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ELECTRONIC MANUFACTURING PROCESS IMPROVEMENT (EMPI) FOR PRINTED WIRING ASSEMBLIES

Program Task 2 Project Description Report

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April 1992

Final Report for Period August 1990 - January 1991

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14 Feb 92
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13. ABSTRACT

This Task 2 Technical Operating Report describes, in detail, the specific experiments that will be conducted under this contract on the integrated manufacturing process for surface mount technology (SMT) printed wiring assemblies (PWAs) at TRW MEAD. This detail includes: 1) The investigative methods used to design the experiments such as full- and fractional factorial techniques; 2) The printed wring board (PWB) design, the component selection and layout, the defect data to be collected, and the inspection criteria used to collect the defect data; and 3) The applicable control limits and the tolerance budgets related to the integrated SMT PWA process flow.

14. SUBJECT TERMS

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INTRODUCTION

The Task 2 Technical Operating Report details, the specific experiments that will be conducted under this contract on the integrated manufacturing process for surface mount technology (SMT) printed wiring assemblies (PWAs) at TRW MEAD. This detail includes: (1) The investigative methods used to design the experiments such as full- and fractional factorial techniques; (2) The printed wiring board (PWB) design, the component selection and layout, the defect data to be collected, and the inspection criteria used to collect the defect data; and (3) The applicable control limits and the tolerance budgets related to the integrated SMT PWA process flow.

1. OVERALL OBJECTIVES AND GOALS

TRW's goal in performing the Electronic Manufacturing Process Improvement (EMPI) project is to identify, quantify (through process capability indices), and improve aspects of process control used in the surface mount printed wiring assembly flow. The resulting benefits of these improvements in the process will be identified and quantified to allow transition of the process improvement technology to others in the industry.

Covered by this study are five subtasks: (1) infrared reflow of PWAs; (2) fine pitch device (FPD) lead tinning; (3) cleaning (which includes a component standoff experiment and a solvent cleaning experiment); (4) FPD lead forming; and (5) placement (which includes a solder paste placement experiment and component placement experiment.

This project concerns all of the potentially significant variables that are controlled and determined outside of the workstation in which the specific experiment is being run (interstation variables). These include the results of any external process equipment variables or manually controlled variables that are impossible to monitor or control at the workstation being used in the specific experiment, yet still contribute directly to that workstation's yield. An example of an interstation variable would be the PWB thickness, which is controlled by the PWB fabricator, according to TRW MEAD drawing requirements, and influences the reflow process yield by introducing variations in the heat required to reflow the PWA due to varying PWB mass.

Initial work has started on developing a cost model that will quantify the benefits attributable to the implementation of the process improvements uncovered as a result of the efforts sponsored by this EMPI program. Although the activity has not been completed, worksheets have been developed and are included as a part of the appendix to this report.

Detailed documentation for the PWB design, the component selection and layout, the five subtask experiments, the product assurance plan, and the data analysis methodology is presented in the appendix to this report.

2. PRINTED WIRING ASSEMBLY DESIGN

The PWB design that was used to run the process capability studies and gather data for the baseline experiments (see Report No. TOR 56310-1) was intended to be used primarily to collect data for solder joint reliability studies. Consequently, large (84-pin) leadless ceramic chip carrier packages that were expected to fail were intentionally included in the component mix so that useful solder joint failure data could be gathered. Also included in the design were two layers of copper-Invar-copper foil that were required to control the coefficient of expansion of PWB and enhance the reliability of solder joints between the PWB and the leadless ceramic chip carriers. Since these characteristics are not appropriate for this EMPI study for technical and cost reasons, a specific design was developed.

2.1 EMPI Printed Wiring Board

A Standard Electronic Module (SEM), Format E size was selected for this EMPI study. This format, approximately 5.6-in by 5.2-in, has become a standard for electronic modules under development for Air Force integrated avionics applications. Polyimide-glass with 1/2-oz/ft^2 copper outer layers and two inner layers of 2-oz/ft2 copper were used in the construction of the PWB. The mass of copper selected simulates the thermal characteristics of copper-Invar-copper without imposing the heavy cost penalty associated with it.

The footprint patterns used for the several components associated with this design were taken from TRW MEAD's design standards. Vias and power/ground layer clearances were provided for all component signal pins, however no circuit interconnections were provided for any of the signals. These interconnections are not considered to be relevant to any of the studies being performed. Connections are made, however between the power and ground pins of all of the components and their respective power and ground planes internal to the PWB. These connections are considered significant in those experiments where heat is applied to form solder joints. The connection between the power and ground pins and the internal layers create a significant heat sink that can affect the solder joints formed at these locations differently than those formed at signal pins.

PWB thickness is a process variable being examined to determine its affect on solder joint formation and component placement characteristics. The PWB design documentation specifies that a group of PWBs be fabricated within very close tolerances (+/- 1-mil) to both the top (68-mil) and bottom (58-mil) range of thickness. Although initially considered by the PWB fabricator as a requirement that could be reasonably met, it was found to be a very expensive requirement for the fabricator.

Another process variable being examined is the affect of feature "stretch" or "shrinkage" on solder paste placement accuracy and component placement accuracy. The PWB design documentation specifies that a second component layer artwork be created that is "stretched" so that the dimension between the fiducials on the outer layer be 3 mils greater than the 'correct' design. This artwork is used to fabricate sets of 'stretched' PWBs.

Another process variable being examined is the style of solderable finish on the PWB. One common finish is accomplished by dipping the PWB in molten solder and blowing off the excess solder with hot air. A second finish uses the more conventional tin-lead plate and fuse technology. Thus the PWB design documentation requires that groups of PWBs be fabricated using each of these finishes.

Process capability studies performed prior to this EMPI program determined that component standoffs could not applied to PWBs in the 4- to 6-mil range, repeatedly. It was also determined that dry film solder mask could be applied to perform this 'component standoff' function. As a result, the PWB documentation includes a requirement to provide artwork for solder mask standoffs for leadless ceramic chip carrier components.

The PWB fabrication documentation is presented in the appendix to this report.

2.2 Component Selection

The selection and placement of components on the PWB was made after first considering the different types of components that would be expected on a 'typical' TRW MEAD avionics SEM E design. Their locations on the PWB were based on those locations most beneficial for gathering experimental data for this EMPI program. Table 1 presents a parts list and quantity of parts that are required to support this program.

It was less expensive, and the lead time was shorter, to order the LCCs and the 132-pin FPDs without the lids that cover the die cavity. These lids were attached at TRW MEAD in the hybrid lab after the parts were received. The LCC parts were received with a gold finish on their terminations, and they are being solder dipped to MIL-STD-2000 requirements by an outside contract service.

The chip capacitors and resistors were received in trays but are required to be in reel format to use on the robotic parts placement workstation. These parts have been put into the reeled format by an outside contract service.

Table 1

Inventory of Parts

Part Number	Quantity	Description
M55342K06B110ER	5267	M55342 chip resistor
CDR02BX103BKU	5821	CDR02 chip capacitor
49BCP	832	CWR06 chip capacitor
PB-C85243	2495	20-pin ceramic chip carrier
PB-44823	1386	28-pin ceramic chip carrier
IRK32F1-200B	1109	32-pin ceramic chip carrier
70-02	192	132-pin FPD (Diacon)
IMKX3F1-4546AA	192*	132-pin FPD (NTK)
PB-F86259	192	132-pin FPD (Kyocera)
786582/A	32	PWB, hot air leveled, no stretch
786582/B	32	PWB, hot air leveled, stretched
786582/C	35	PWB, fused, no stretch
786582/D	35	PWB, fused, stretched
786582/E	8	PWB, fused, no stretch, thick
786582/F	8	PWB, fused, no stretch, thin
RHF63	7	solder paste, Metech
SN62RM92A90	11	solder paste, Multicore

* not received as of the date of this report

The detailed component descriptions can be found in the appendix to this report.

3. DESIGN OF EXPERIMENTS

The goal of this EMPI for Printed Wiring Assemblies Program is to understand and quantify the process variables that have significant affects on process responses that are critical to the manufacture of military avionics printed wiring assemblies. The measures of this are the process capability indices known as Cp and Cpk. Experiments are designed around the PWB assembly processes in order to arrive at values for these process capability indices. This experimental design process methodology consists of five basic steps, four of which are repeated for each process examined. For this program there are five subtasks that involve a total of seven experiments each requiring the application the the DOE methodology.

The first step is to identify the process flow to be studied. This was done as part of the Task 1, Baseline phase of this program and is presented here as Figure 1. The workcells identified in Figure 1 are the "core" of the PWB assembly process.

The second step in the process identifies critical process responses, or outputs, and all suspected process variables or inputs that influence the responses. This has been accomplished at a brainstorming session attended by process and manufacturing engineers and technicians that are familiar with the assembly process and equipment. The output of this step is a "Cause and Effect" diagram for each experiment that is the foundation of the design for that experiment. These "Cause and Effect" diagrams are presented in the sections describing the individual experimental designs.

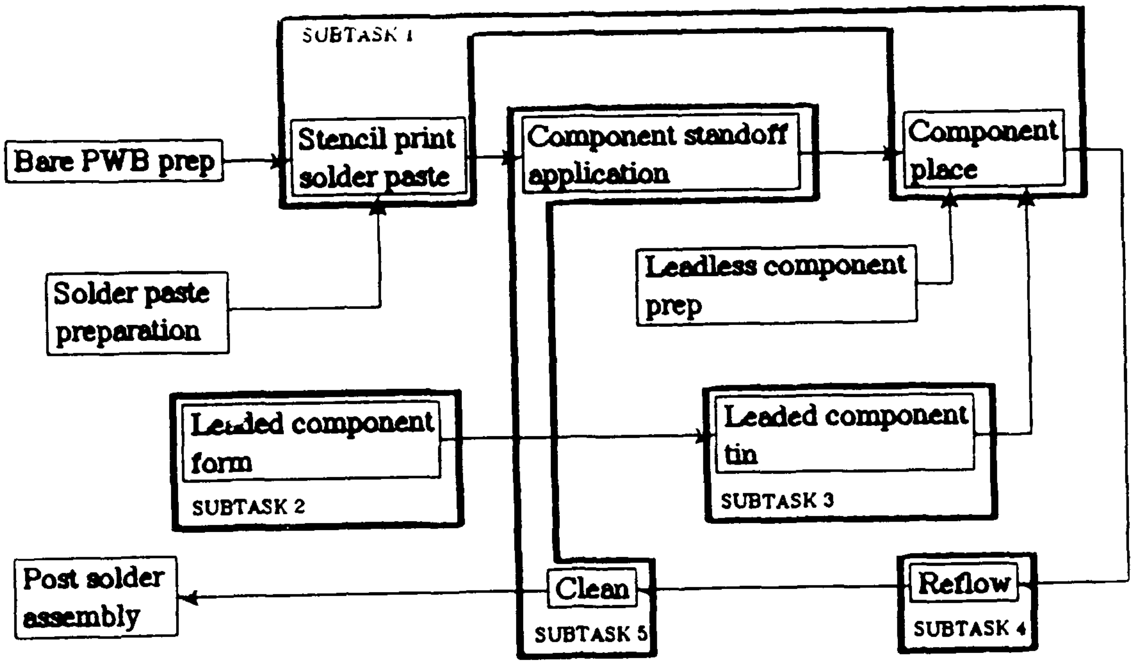


Figure 1 EMPI Process Flow Diagram

The third step in the process quantifies the process variables and responses and establishes the measurement methods used to collect the data from the experiment. The values of the responses have been taken, for the most part, from a frequently imposed contractual requirement document such as MIL-STD-2000 or an internally generated requirement such as a material or process specification or workmanship standard. This process is usually involved and subjected to revision or reiteration if the specification is a part of a system where the goal is to share a tolerance budget equally among several processes. During this step of the process, measurement techniques used to collect data are identified and developed. The goal is to maintain an order of magnitude margin between the data values and the measurement precision. For example, if a response is expected to have a measured value of four mils, the precision of the measurement needs to be at least 0.4 mils. This goal may not be achievable in all instances. An example is where there is property such as roughness is compared against a visual standard and ranked from one to five. Once an experiment has been finalized and started, no changes should be incorporated.

The fourth step in the process establishes the relationships between the process variables and responses for each experiment to be performed. This is an important step in the experimental design process and identifies the contents of each experiment. This relationship is determined by establishing a process variable/results matrix table with the response listed in an outer column and the process variables listed along the top row. It is at this point that the selection of the type of experiment matrix is made. Where three or fewer process variables are being examined, the selection of a full factorial design is warranted, because the number of experimental runs per design is not prohibitive. Where more than three, but less than seven process variables have been chosen, a fractional factorial experimental design is appropriate. The assumptions that are made for the fractional design are that there are no interaction effects among the process variables and that the effects of the process variables on the response are linear. This hypothesis must be tested for fractional factorial design by running a reflected (or folded) design which identifies interactions. Since the goal of the experiment is to obtain the maximum response due to the low-to-high transition in process variables, all of the experiments are based on a two-level design. The detailed experiment table can be represented by a classic 'plus/minus' matrix with the response to be observed and the process variables to be exercised heading the columns with the experiment run numbers leading the rows. This table gives the exact recipe for each experiment run.

A full factorial design should be replicated at least once to enable the variability of the design to be established. Interactions and experimental error effects can be shaken out of the full factorial with this replication run.

A fractional factorial design is a different matter. Since process variables are assigned to columns in the matrix that would normally be assigned to collect interaction effects, any significant effects logged for these columns must be identified as due to interactions or due to the interloping process variable. If neither direct nor interactive effects are noted, the data in these columns may be used to measure the experimental error. This error will give an experimenter an indication whether or not a significant process variable has been overlooked.

The experimental runs are performed as required by the matrix, and the data is gathered and logged for analysis by a technique known as Analysis of Variance (ANOVA). This technique is described in detail in the appendix to this report.

The fifth and final step in this process implements the results obtained. Process variables that need to be improved, as determined by the analysis of the experimental data, will be improved as indicated and verified by additional experimentation. The process variables that are identified as being required to be brought under control will be brought under control. The limits of that control will come from the analysis of the experimental data also. Many of the process variable limits that are equipment related are actually monitored in a closed loop fashion by the equipment. This lends itself readily to automated tracking and reporting since the process variable data can be automatically collected by a shop floor management system. Other process variables need to be manually tracked and entered into the shop floor management system.

The TQM methodology implemented by this EMPI program implies that there is a never ending process improvement cycle in place. Data is provided to indicate where improvement can best be made, and advantage must be taken of that information constantly if TQM is to be meaningful.

4. DESCRIPTION OF EXPERIMENTS

An outline of each experiment for the five subtasks is presented in this section. The order in which the detail is given is by subtask and not by the logical process flow. This discrepancy between subtask flow and logical process flow arose because of the way in which the proposal was written. For each subtask a description of the experiment to be run is presented followed by a "Cause and Effect" diagram; a list of response variables and their levels, measurement methods, and their requirements source; a list of response variables and their measurements and requirements source; and finally an experimental matrix

4.1 Subtask 1, Infrared Reflow

Infrared reflow is the process that forms the solder joints between the components and the PWB using the deposited solder paste as the source for the solder and flux. The infrared reflow oven uses ten thermal zones and a conveyor to control the temperature on the PWB and the rate that it changes on the PWB. The process variables that are encircled on the "Cause and Effect" (Figure 2) diagram are those that are being studied in this contract. Those process variables that are not encircled were studied prior to the implementation of this contract. The 'PWB thickness' process variable is being studied in a separate, single point experiment that is designed to yield the magnitude of the effect of PWB thickness on solder joint temperature. This single point experiment came about as a result of identifying more process variables to test than the seven that an eight run fractional factorial could handle.

This experiment is looking at seven process variables and seven responses in addition to the PWB thickness process variable and solder joint temperature response being determined in the single point experiment previously mentioned. These variables are presented in Tables 2 and 3, respectively.

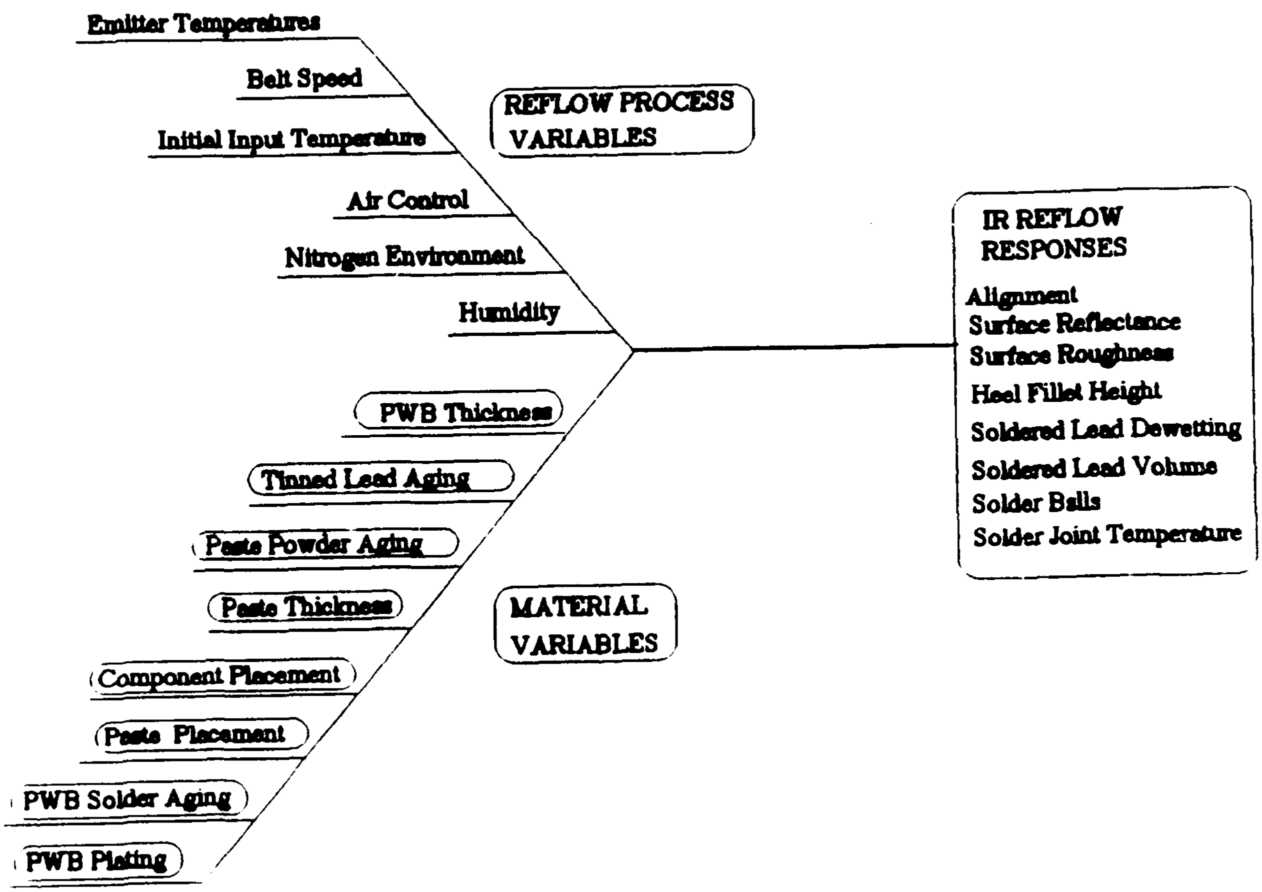


Figure 2 IR Reflow Cause and Effect Diagram

Table 2 IR Reflow Process Variable Details

Process Variable	Measuring Device/ Precision	Variable Range	Specification
**PWB thickness	Dial micrometer/ +/- 0.1-mil	58 to 68 mils	PWB fabrication drawing
**Tinned lead aging	Steam ager/ ±1 min	0 to 8 hrs	Engineering judgment
**Solder paste aging	Oven with timer/ +/- 15 min	24 hrs at 95° C	Engineering judgment
**Solder paste deposit thickness	Dial micrometer/ +/- 0.1-in	4/10-mil to 6/12-mil	Engineering judgment
**Component placement	Microscope with filar/ +/- 0.1-mil	+/- 2.5 mil from nominal	MIL-STD-2000
**Solder paste deposit placement	Microscope with filar/ +/- 0.1-mil	+/- 3.5 mils from nominal	MM 2-1
**PWB plating	Inspection/ +/- 0	Reflowed tin-lead and solder dipped/hot air leveled	TRW design options
**PWB plating aging	Steam ager/ +/- 1 min	0 to 6 months	Engineering judgment

** Process variables being studied by this experiment.

Table 3 IR Reflow Response Variable Details

Response Variable	Measuring Device/ Precision	Specification Limit	Specification
Lead/pad alignment	Microscope with filar +/- 0.1-mil	+/- 2.5 mils from nominal	MIL-STD-2000
Solder joint reflectance	Visual comparison/ NA	Flat (1) to specular (5)	Engineering judgment
Solder joint finish	Visual comparison/ NA	Smooth (1) to rough (5)	Engineering judgment
Solder heel fillet height	Microscope with filar/ +/- 0.1-mil	0 to 100% of "calf" length	MM 3-23
FPD soldered lead dewetting	Microscope with particle counting grid/NA	0 to 5% of soldered area	MM 3-22
FPD soldered lead solder volume	Visual comparison/ NA	No lead-to-pad fillet extending over top of lead foot and beyond edge	MM 3-21 and MM 3-22
Solder balls	Microscope with filar/ +/- 0.1-mil	0 to 5 mils	MM 5-6
Solder joint temperature	MOLE with thermocouple/ +/- 1° C	Nominal +/- 6 C	MIL-STD-2000

Table 4. IR Reflow Experimental 'Recipe'

Standard Order Trial Number	A Solder Paste Thickness mils		B Paste Powder Aging hrs/95 deg C		C Tinned Lead Steam Aging hours		AB Paste Deposit Registration mils		AC PWB Solder Steam Aging hours		BC Comp. Place Registration mils		ABC PWB Type		RESPONSE
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	
1	4/10		0		0			3.5		8		2.5	fused		
2	4/10		0			8		3.5	0		0			air	
3	4/10			24	0		0			8	0			air	
4	4/10			24		8	0		0			2.5	fused		
5		6/12	0		0		0		0			2.5		air	
6		6/12	0			8	0			8	0		fused		
7		6/12		24	0			3.6	0		0		fused		
8		6/12		24		8		3.5		8		2.5		air	

4.2 Subtask 2, Fine Pitch Device Lead Tinning

Fine pitch device lead tinning is the process that applies a coating of solder to the leads of fine pitch devices in order to enhance the formation of the solder joint between the fine pitch device and the PWB. This process is accomplished on a Gelzer robotic station that has a both a component placement arm and a component preparation and tinning arm. The robot takes components with formed leads and fluxes the leads, dips them into a solder pot, and cleans them in a solvent tank. The process variables that are encircled on the "Cause and Effect" (Figure 3) diagram are those that are being studied in this contract. Those process variables that are not encircled were studied prior to the implementation of this contract.

This experiment is looking at three process variables and six responses. These variables are presented in Tables 5 and 6, respectively.

This experiment is an eight run full factorial design that does not require that a reflected or folded design be run to sort out any interaction effects. The 'recipe' for the experimental runs is presented in Table 7. Note that the run order will be randomized. A table similar to this will be used for each response, to calculate any significant effects that a process variable has on that response. An example of how significant effects are calculated is presented in the analysis section of this report.

A replicate experiment is required to determine the experimental error or noise so that a determination can be made whether or not process variables that have a significant effect on a response have been overlooked. With the exception of rerandomizing the run order, no changes are required to be made in the recipe for the experiment.

4.3 Subtask 3, Experiment 1, Component Standoff

This component standoff experiment is examining the effects that several process variables on the response of standoff height. The standoffs are applied by depositing four cylindrical posts of dry film solder mask within the footprint pattern of each leadless ceramic chip carrier. This is a process that is being performed by a contract service using PWBs and artwork supplied by TRW MEAD. TRW MEAD will be monitoring and directing the activity at the vendor's site. The process variables that are encircled on the "Cause and Effect" (Figure 4) diagram are those that are being studied in this contract. Results from previous experiments demonstrated that the adhesive dot dispensing technique have too great a variability to be useful for this application.

This experiment is looking at seven process variables and one response. These variables are presented in Tables 8 and 9, respectively.

This experiment is an eight run fractional factorial design that requires that a reflected or folded design be run to sort out any interaction effects and quantify experimental error. The 'recipe' for the experimental runs is presented in Table 10. Note that the run order will be randomized. A table similar to this will be used for each response, to calculate any significant effects that a process variable has on that response. An example of how significant effects are calculated is presented in the analysis section of this report.

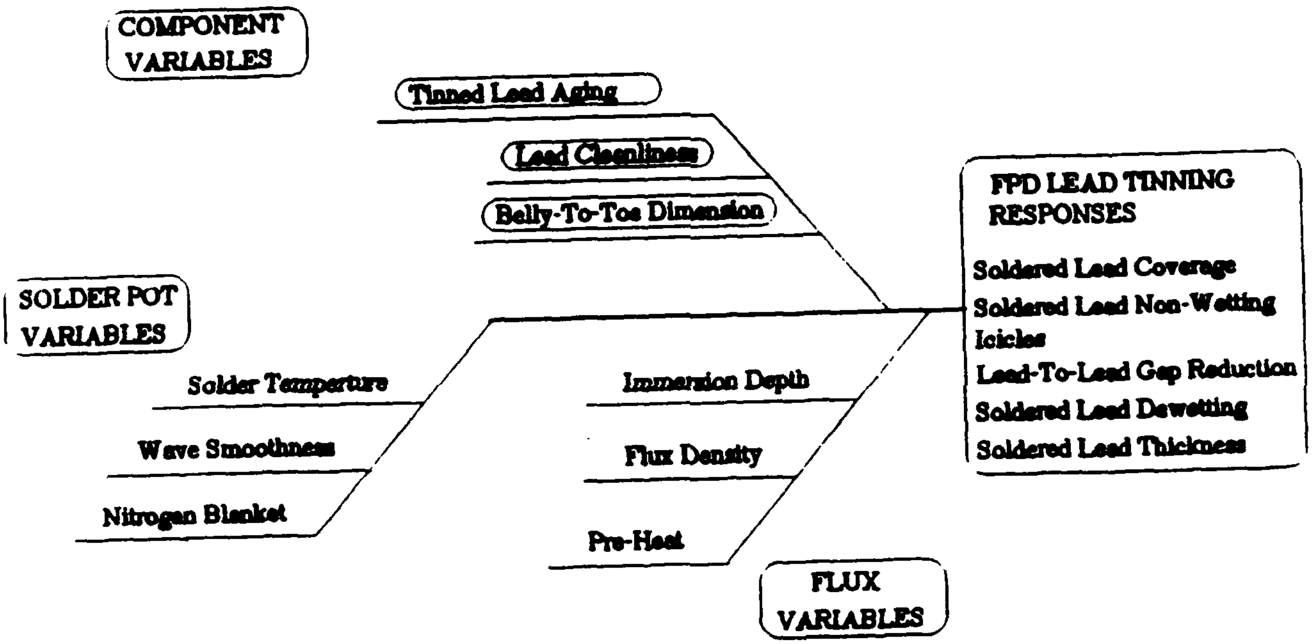


Figure 3 FPD Component Tinning Cause and Effect Diagram

Table 5 FPD Tinning Process Variable Details

Process Variable	Measuring Device/ Precision	Variable Range	Specification
**Lead aging	Steam aging cabinet/ +/- 1 min	0 to 8 hr (0 to 12 mo.)	Engineering judgment
**Lead cleanliness	10% soln. of oil/ +/- 1%	Clean to contaminated	Engineering judgment
**Belly-to-toe dimension	Microscan/ +/- 0.15 mil	4 to 12 mil	TRW cleaning study

Table 6 FPD Tinning Response Variable Details

Response Variable	Measuring Device/ Precision	Specification Limit	Specification
Solder coverage at "calf"	Microscope with filar/ +/- 0.2 mil	25% to 100% of lead below knee (none at knee bend)	MM 1-6, 1-7
Solder thickness at mid- "calf"	Microscope with filar/ +/- 0.2 mil (cross section)	0.1 to 1 mil	Engineering judgment
Non-wet solder surface	Microscope with particle counting grid/NA	0 to 5% of area	MM 1-9
De-wet solder surface	Microscope with particle counting grid/NA	0 to 5% of area	MM 1-9
Icicles	Microscope with filar/ +/- 0.2 mil	0 to 10 mil	MM 1-9
Lead-to-lead gap reduction	Microscope with filar/ +/- 0.2 mil	0 to 10 mil	Engineering judgment

Table 7 FPD Tinning Experimental 'Recipe'

Standard Order Trial Number	A		B		C		AB		AC		BC		ABC		RESPONSE
	Belly-To-Toe Dimension mils		FPD Lead Steam Aging hours		FPD Lead Cleanliness										
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	
1	4		0		clean										
2	4		0			contam									
3	4			8	clean										
4	4			8		contam									
5		12	0		clean										
6		12	0			contam									
7		12		8	clean										
8		12		8		contam									

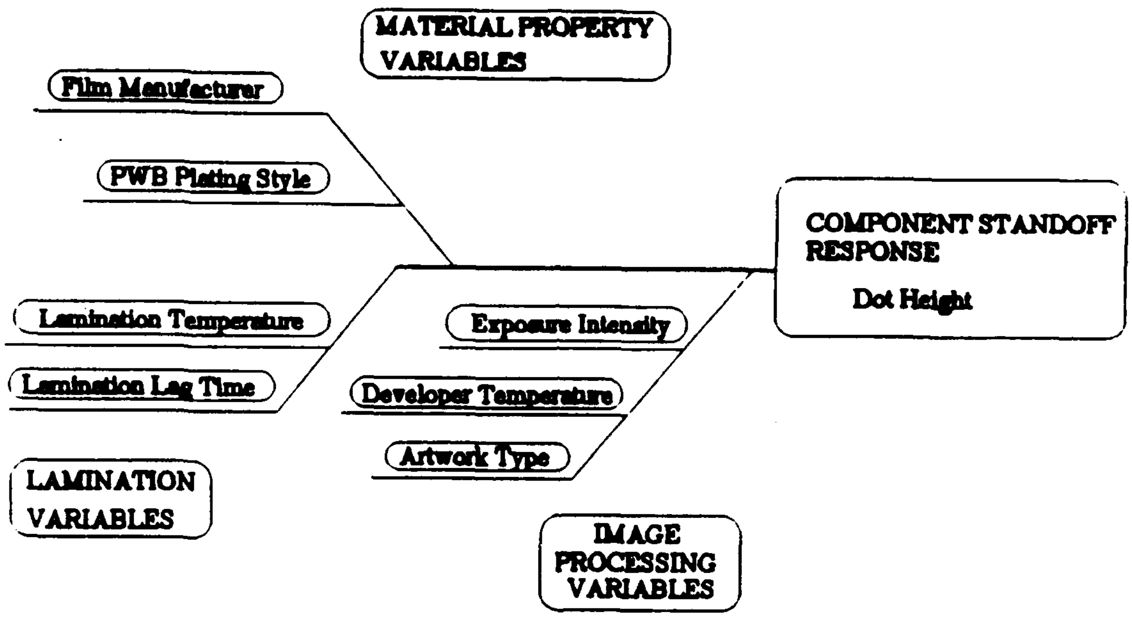


Figure 4 Component Standoff Cause and Effect Diagram

Table 8 Component Standoff Process Variable Details

	Process Variable	Measuring Device/ Precision	Variable Range	Specification
*	Dry film developer temperature	Thermocouple indicato +/- 1° F	90 to 105° F	Vendor product data
*	Dry film exposure intensity	Watt meter +/- 10 W	2500 to 5000 W	Vendor product data
*	Solder mask vendor	Invoice	DuPont and Dynachem	TRW design options
*	PWB plating style	Invoice	Fused tin-lead and solder dip and hot air leveled	TRW design options
*	Lamination temperature	Thermocouple/ +/- 1° C	Nominal +/- 5° C	Vendor product data
*	Lamination lag time to processing	Clock/ +/- 10 min	Nominal plus 24 hours	Vendor product data
*	Style of process film	Visual	diazo and silver halide	General shop practice

* Process variable being studied by this experiment

Table 9 Component Standoff Response Variable Details

Response Variable	Measuring Device/ Precision	Specification Limit	Specification
Standoff dot height	Surface Gauge/ +/- 0.1 mil	4 to 6 mil	Baseline document

Table 10 Component Standoff Experimental 'Recipe'

Random Order Trial Number	Standard Order Trial Number	PWB Serial Number	A		B		C		AB		AC		BC		ABC		RESPONSE
			Dry Film Vendor		Exposure Intensity watts		Developer Temperature deg F		Dry Film Lam. Temp. C from nom		Dry Film Proc Lag Time hours		PWB Style		Process Film Style diazo/halide		
			1	2	1	2	1	2	1	2	1	2	1	2	1	2	
4	1	A-26	DuP		2500		90			+5		24		air	diazo		
5	2	C-106	DuP		2500			105		+5	0		fused			halide	
8	3	C-131	DuP			5000	90		-5			24	fused			halide	
3	4	A-30	DuP			5000		105	-5		0			air	diazo		
1	5	B-60		Dyn	2500		90		-5		0			air		halide	
6	6	D-166		Dyn	2500			105	-5			24	fused		diazo		
7	7	D-167		Dyn		5000	90			+5	0		fused		diazo		
2	8	B-66		Dyn		5000		105		+5		24		air		halide	

The reflected experimental matrix is developed by swopping the high and low limits of the process variables for each column and row. For example, instead of using the low limit of 1500 watts for 'Exposure Intensity' in run No. 1 in Table 10, the high limit of 2500 watts is used.

4.4 Subtask 3, Experiment 2, PWA Cleaning

This experiment is examining the effects that several process variables have on the responses of visual and ionic contamination of PWAs. This cleaning process uses an in-line spray cleaner that has three spray zones, two dip tanks, and a final distillate spray rinse zone. The spray temperatures and pressures and the conveyor speeds are all controllable on the cleaner. The process variables that are encircled on the "Cause and Effect" (Figure 5) diagram are those that are being studied in this contract. Those process variables that are not encircled were studied prior to the implementation of this contract.

This experiment is looking at five process variables and two responses. These variables are presented in Tables 11 and 12, respectively.

This experiment is an eight run fractional factorial design that requires that a reflected or folded design be run to sort out any interaction effects and quantify experimental error. The 'recipe' for the experimental runs is presented in Table 13. Note that the run order will be randomized. A table similar to this will be used for each response, to calculate any significant effects that a process variable has on that response. An example of how significant effects are calculated is presented in the analysis section of this report.

The reflected experimental matrix is developed by swopping the high and low limits of the process variables for each column and row. For example, instead of using the low limit of 80 percent for "Nitrogen Concentration" in run No. 1 in Table 13, the high limit of 96 percent is used.

4.5 Subtask 4, Fine Pitch Device Lead Forming

Fine pitch device lead forming is the process that bends and trims the leads of fine pitch devices to a form that allows them to fit onto the footprint patterns created for them on the PWB. It also provides clearance between the bottom of the FPD and the PWB for cleaning enhancement. This process is accomplished on a Gelzer robotic station that has a both a component placement arm and a component preparation and tinning arm. The robot takes components with unformed leads and places them into a die that it controls. The robot then actuates the forming and trimming die, removes the FPD from the die, and presents it for the FPD tinning process. The process variables that are encircled on the "Cause and Effect" (Figure 6) diagram are those that are being studied in this contract. Those process variables that are not encircled were studied prior to the implementation of this contract.

This experiment is looking at three process variables and four responses. These variables are presented in Table 14, and 15 respectively.

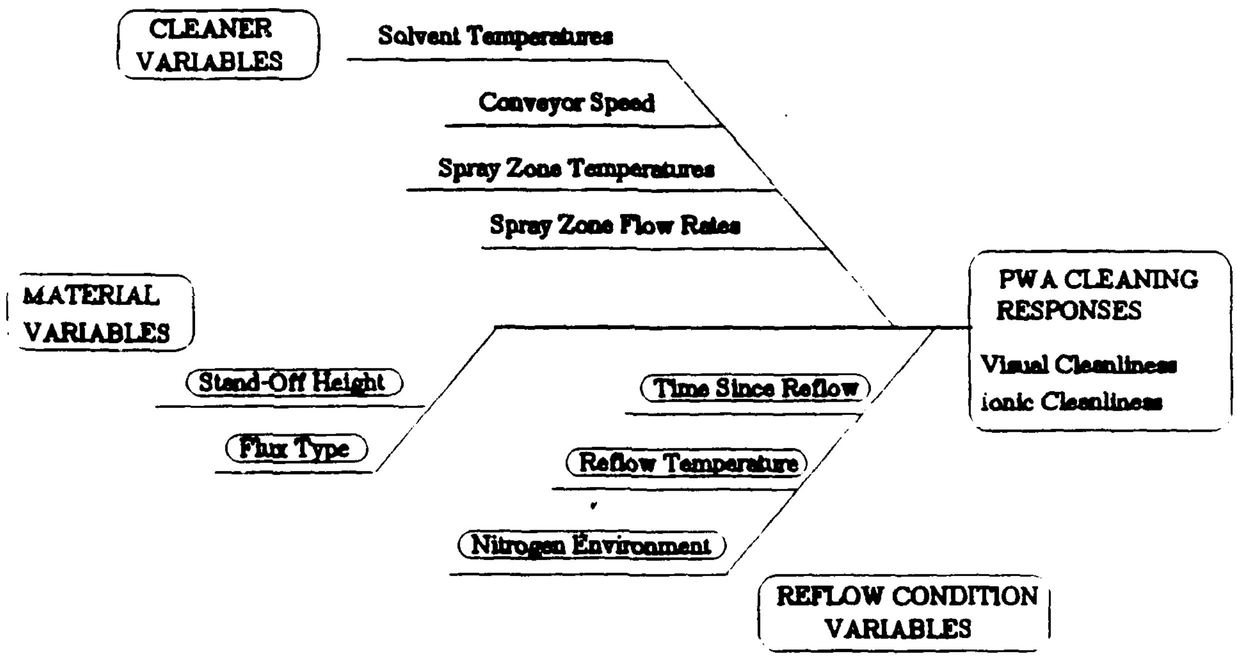


Figure 5 PWA Cleaning Cause and Effect Diagram

Table 11 PWA Cleaning Process Variable Details

	Process Variable	Measuring Device/ Precision	Variable Range	Specification
*	Time since reflow	Timer/ +/- 1 min	0 to 30 min	Baseline document
*	Reflow temperature	Thermocouple/ +/- 1° C	210 to 220° C	Baseline document
*	Nitrogen environment	Oxygen analyzer/ +/- 2 percent	70 to 98 percent	Baseline document
*	Component stand-off height	Surface gauge/ +/- 0.1-mil	4 to 6 mil	Baseline document
*	Solder paste vendor	not applicable	Metech and Multicore	TRW solder paste evaluation

* Process variable being studied by this experiment

Table 12 PWA Cleaning Response Variable Details

Response Variable	Measuring Device/ Precision	Specification Limit	Specification
Visual cleanliness	Comparison to visual standards/ +/- 1 unit	1 to 5 units	MIL-P-28809
Ionic cleanliness	Ionic contamination tester/+/- 1 ugm NaCl/sq in	0 to 10 ugm NaCl/sq in	MIL-C-28809

Table 13 PWA Cleaning Experimental 'Recipe'

Standard Order Trial Number	A		B		C		AB		AC		BC		ABC		RESPONSE
	Nitrogen Concentration percent		IR Reflow Temperature deg C		Time Since IR Reflow minutes		Solder Paste Vendor		Standoff Height mils						
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	
1	80		210		0			Mult		6					
2	80		210			30		Mult	4						
3	80			220	0		Met			6					
4	80			220		30	Met		4						
5		98	210		0		Met		4						
6		98	210			30	Met			6					
7		98		220	0			Mult	4						
8		98		220		30		Mult		6					

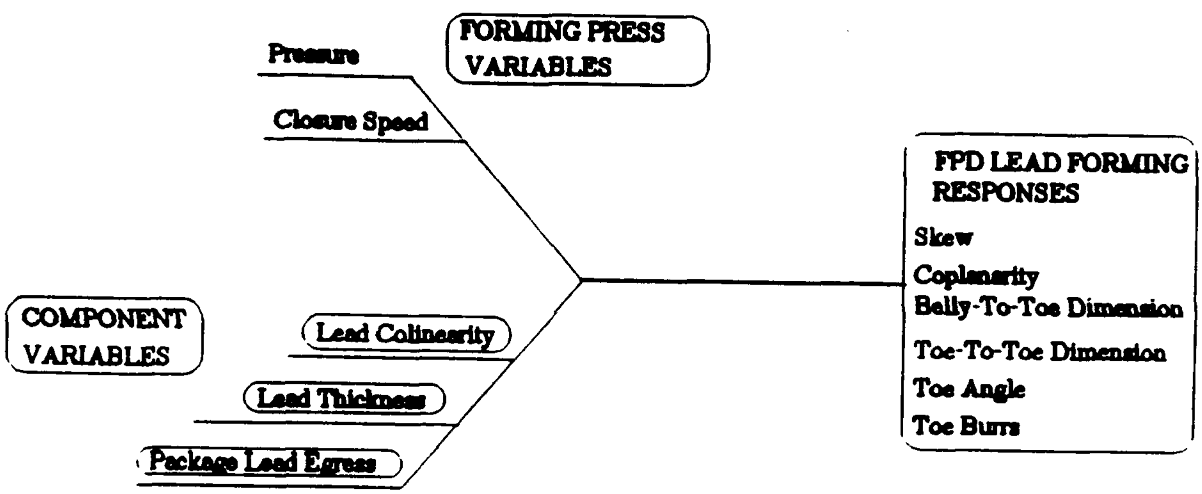


Figure 6 FPD Lead Forming Cause and Effect Diagram

Table 14 FPD Lead Forming Process Variable Details

Process Variable	Measuring Device/ Precision	Variable Range	Specification
**Lead colinearity	Microscope with filar/ +/- 0.1-mil	+/- 3 mil from orthogonal	Engineering
**Lead thickness	Micrometer/ +/- 0.1-mil	5 to 8 mil	Vendor drawing requirements
**Lead package egress	Microscan/ +/- 0.1-mil	From top of package or side of package	Vendor drawing requirements

Table 15 FPD Lead Forming Response Variable Details

Response Variable	Measuring Device/ Precision	Specification Limit	Specification
Skew	Microscope with filar/ +/- 0.1-mil	-2 to +2 mil from orthogonal	MIL-STD-2000
Coplanarity	Microscan/ +/- 0.1-mil	4 mil maximum deviance	Engineering
"Belly-to-toe" dimension	Microscan/ +/- 0.1-mil	10 milsl +/- 2 mil	TRW drawing
"Toe-to-toe" dimension	Coordinatograph/ +/- 0.1-mil	Nominal/ +/- 5 mil	TRW drawing
"Toe" angle dimension	Microscan/ +/- 0.1-mil	+/- 15° from horizontal	MIL-STD-2000
"Toe" burrs	Microscope with filar/ +/- 0.1 mil	1x lead thickness, max.	MIL-STD-2000

This experiment is an eight run full factorial design that does not require that a reflected or folded design be run to sort out any interaction effects. The 'recipe' for the experimental runs is presented in Table 16. Note that the run order will be randomized. A table similar to this will be used for each response, to calculate any significant effects that a process variable has on that response. An example of how significant effects are calculated is presented in the analysis section of this report.

A replicate experiment is required to determine the experimental error or noise so that a determination can be made whether or not process variables that have a significant effect on a response have been overlooked. With the exception of rerandomizing the run order, no changes are required to be made in the recipe for the experiment.

Table 16. FPD Lead Forming Experimental 'Recipe'

Standard Order Trial Number	A FPD Lead Egress		B FPD Lead Thickness mils		C FPD Lead Skew mils		AB		AC		BC		ABC		RESPONSE
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	
1	side		5		nom										
2	side		5			+3									
3	side			8	nom										
4	side			8		+3									
5		top	5		nom										
6		top	5			+3									
7		top		8	nom										
8		top		8		+3									

4.6 Subtask 5, Experiment 1, Solder Paste Deposit

Solder paste deposit is the process that precisely applies a fixed amount of solder paste (a mixture of solder powder and flux) onto the footprint pattern of PWBs. This is the material that provides the solder required to effect a joint between the PWA component and PWB. This process is accomplished by an automated stencil machine that automatically aligns the PWB to the stencil prior to the squeegeeing the solder paste onto the PWB. The process variables that are encircled on the "Cause and Effect" (Figure 7) diagram are those that are being studied in this contract. Those process variables that are not encircled were studied prior to the implementation of this contract.

This experiment is looking at three process variables and five responses. These variables are presented in Table 17 and 18, respectively.

This experiment is an eight run full factorial design that does not require that a reflected or folded design be run to sort out any interaction effects. The 'recipe' for the experimental runs is presented in Table 19. Note that the run order will be randomized. A table similar to this will be used for each response, to calculate any significant effects that a process variable has on that response. An example of how significant effects are calculated is presented in the analysis section of this report.

A replicate experiment is required to determine the experimental error or noise so that a determination can be made whether or not process variables that have a significant effect on a response have been overlooked. With the exception of rerandomizing the run order, no changes are required to be made in the recipe for the experiment.

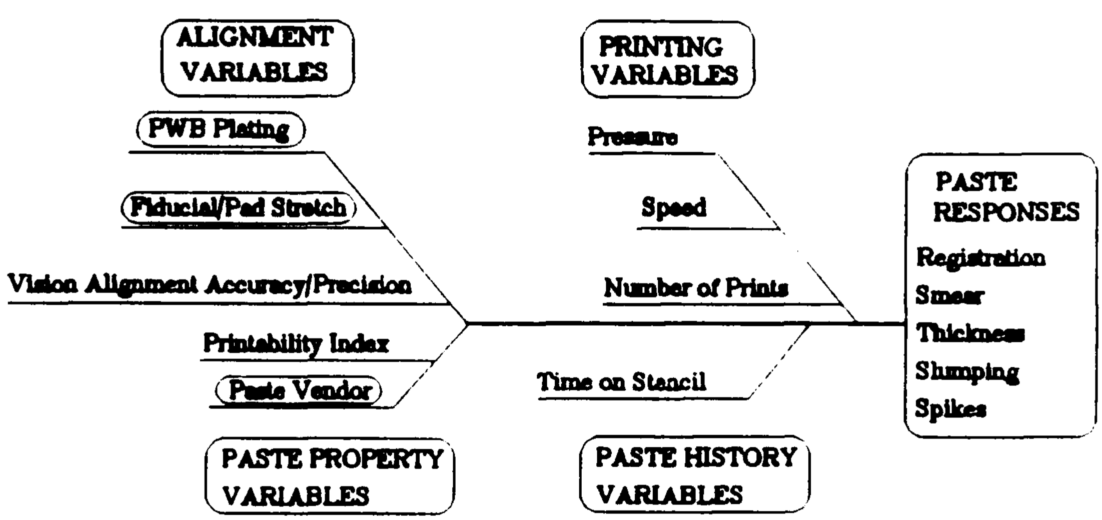


Figure 7 Solder Paste Deposit Cause and Effect Diagram

Table 17. Solder Paste Deposit Process Variable Details

Process Variable	Measuring Device/ Precision	Variable Range	Specification
**Fiducial pad stretch	Coordinatograph +/- 0.1 mil	+3.0 mil from nominal	PWB fabrication drawing
**PWB plating	Inspection/ +/- 0	Reflowed tin-lead and solder dipped/hot air leveled	MEAD Design options
**Solder paste vendor	Inspection/ +/- 0	Metech RF63 and Multicore Sn62-RM92A90	MEAD solder paste study

* Depends on viscosity of solder paste used.

** Process variables being studied by this experiment.

Table 18. Solder Paste Deposit Response Variable Details

Response Variable	Measuring Device/ Precision	Specification Limit	Specification
Registration	Microscope with filar/ +/- 0.1-mil	deposit overhang </=25% of pad axis in direction measured	MM para. 2-1
Smear	Microscope with filar/ +/- 0.1-mil	print separation >25% of design spacing	MM para. 2.3
Thickness	Microscan/ +/- 0.1-mil	+/- 20% of stencil thick. at location measured.	MM para. 2.5
Slumping	Microscope with filar/ +/- 0.1-mil	print separation >25% of design spacing.	MM para. 2.7
Spikes	Microscan +/- 0.1-mil	<1 times 't' of stencil thick at location measured.	MM para. 2.7

Table 19. Solder Paste Deposit Experimental "Recipe"

Random Order Trial Number	Standard Order Trial Number	PWB Serial Number	A		B		C		AB		AC		BC		ABC		RESPONSE
			Solder Paste Vendor		Fiducial Stretch mils		PWB Style		INTERACTION AND ERROR TERMS								
			1	2	1	2	1	2	1	2	1	2	1	2	1	2	
7	1	A-26	Met		0		fused										
1	2	C-106	Met		0			air									
8	3	C-131	Met			+3	fused										
3	4	A-30	Met			+3		air									
2	5	B-60		Multi	0		fused										
6	6	D-156		Multi	0			air									
5	7	D-157		Multi		+3	fused										
4	8	B-66		Multi		+3		air									

4.7 Subtask 5, Experiment 2, Component Placement

Component placement is the process that precisely locates components onto the surface of a PWB that has had solder paste deposited onto its footprint patterns. This is performed with the Gelzer robotic workstation which has both a component preparation and a component placement arm. The placement arm picks the component out of a presentation fixture, determines its location in space, then places it on the PWB after having determined the location of the PWB in space. The process variables that are encircled on the "Cause and Effect" (Figure 8) diagram are those that are being studied in this contract. Those process variables that are not encircled were studied prior to the implementation of this contract.

This experiment is looking at five process variables and two responses. These variables are presented in Tables 20, and 21, respectively.

This experiment is an eight run fractional factorial design that requires that a reflected or folded design be run to sort out any interaction effects and quantify experimental error. The 'recipe' for the experimental runs is presented in Table 22. Note that the run order will be randomized. A table similar to this will be used for each response, to calculate any significant effects that a process variable has on that response. An example of how significant effects are calculated is presented in the analysis section of this report.

The reflected experimental matrix is developed by swopping the high and low limits of the process variables for each column and row. For example, instead of using the low limit of 0 hours aging for "Solder Paste Aging" in run No. 1 in Table 22, the high limit of 3 hours is used.

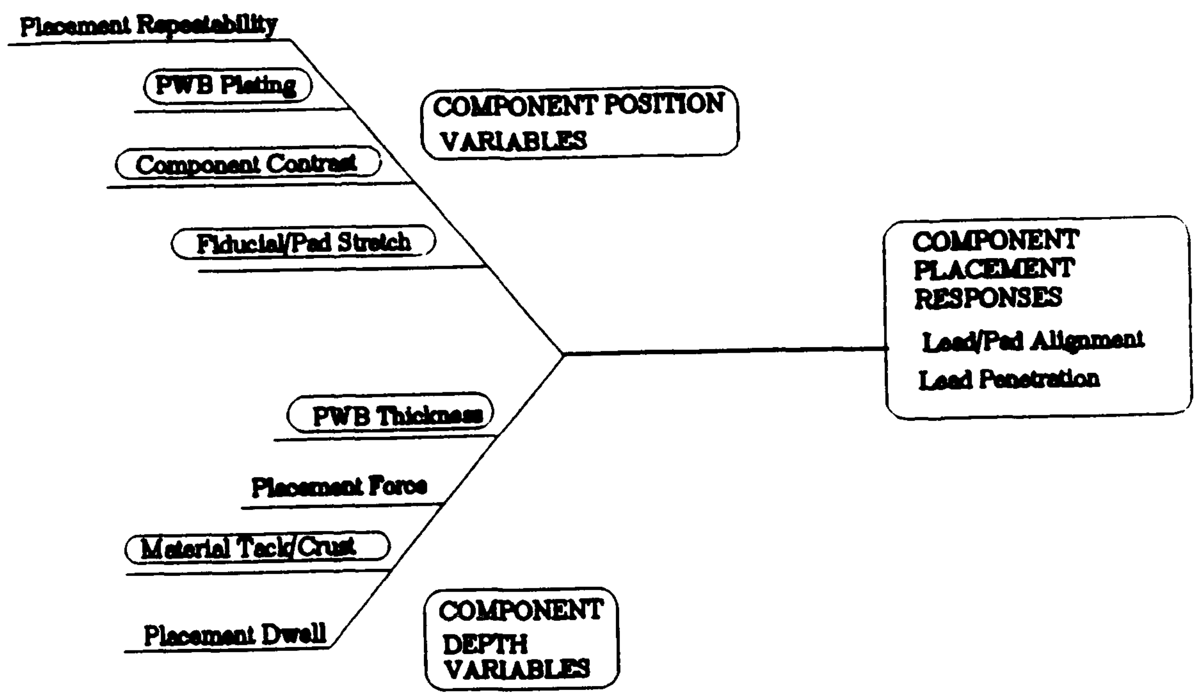


Figure 8 Component Placement Cause and Effect Diagram

Table 20 Component Placement Process Variable Details

Process Variable	Measuring Device/ Precision	Variable Range	Specification
**Solder paste open time	Timer/ +/- 1 sec	0.5 to 3 hrs	Assembly staging time
**PWB plating	Inspection/ +/- 0	Reflowed tin/ lead and solder dipped/hot air leveled	MEAD design options
**Tinned lead aging	Steam ager/ +/- 1 min	0 to 8 hrs	Engineering judgment
**Fiducial pad stretch	Coordinatograph/ +/- 0.1-mil	+/- 3 mil from nominal	PWB fabrication drawing
**PWB thickness	Dial micrometer/ +/- 0.1-mil	58 to 68 mil	PWB fabrication drawing

**Process variables being studied by this experiment.

Table 21 Component Placement Response Variable Details

Response Variable	Measuring Device/ Precision	Specification Limit	Specification
Lead/pad alignment	Microscope with filar +/- 0.1-mil		MIL-STD-2000
Chip component overhang		10% of termination width, max	
Lap		5 mil, max	
Lead and toe overhang		25% of lead width, max or 20 mil, max; whichever is greater	
Heel clearance		100% of lead width	
Leadless chip carrier overhang		25% of castellation width, max	MM 3.3
Lead penetration into solder paste	Microscan/ $\pm$0.1-mil	No air gap to 3 mil	MEAD placement study

Table 22. Component Placement Experimental 'Recipe'

Standard Order Trial Number	A		B		C		AB		AC		BC		ABC		RESPONSE
	Tinned Lead Aging hrs		PWB Type		Solder Paste Aging hrs		PWB Thickness mils		Fiducial Stretch mils						
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	
1	0		air		0			68		+3					
2	0		air			3		68	nom						
3	0			fuse	0		58			+3					
4	0			fuse		3	58		nom						
5		8	air		0		58		nom						
6		8	air			3	58			+3					
7		8		fuse	0			68	nom						
8		8		fuse		3		68		+3					

APPENDIX

APPENDIX

Detailed Experimental Plans

- Subtask 1, IR Reflow
- Subtask 2, FPD Lead Tinning
- Subtask 3-1, Component Standoff
- Subtask 3-2, PWA Cleaning
- Subtask 4, FPD Lead Forming
- Subtask 5-1, Solder Paste Placement
- Subtask 5-2, Component Placement

Guidelines for Calculating EMPI Process Capability Indices

PWB Design Documentation

Bill of Materials

Product Assurance Plan

Cost Model Worksheets

Interoffice Correspondence
TRW Avionics & Surveillance Group

91.Q602.PCC.ST1.0

Subject	Date	From
Detailed Experimental Plan Infrared Reflow (ST10)	25 January 1991	P. CREPEAU
To	**cc**	**Location/Phone**
P. Glaser	D. Cavanaugh P. Finkenbinder J. Murray T. Neillo	RC4/1073/3182

I INTRODUCTION

This IOC presents the detailed experimental plan and procedures for performing the Sub Task 1 experimental procedure. This experiment is designed to identify significant inter-workstation process variables that effect several responses for the infrared reflow work cell. The significant process variables were identified in a "brainstorming" session among several manufacturing and process engineers. Figure 1 presents a cause and effect diagram that identifies the process variables and responses for the infrared reflow work cell. The shaded process variables are those being evaluated in this experiment. The unshaded process variables are intrastation variables that were previously evaluated and reported.

Ranges (or levels) for the process variables were selected based on tolerances that were expected to be encountered on the factory floor. These ranges, the instruments used to measure the variables, and the reference to the source for the ranges are presented in Table 1. Double asterisks identify those process variables being evaluated by this experiment. Responses to be analyzed for the infrared reflow workstation, the instruments used to measure the responses, the specification limits for the responses, and the source for the specification limits are presented in Table 2. The main experimental design is an eight run fractional factorial with seven variables. One reflection is required and will be run.

Table 3 presents the form that will be used for each response evaluated by this main experimental design. A single point experiment is also being designed in which the effect of PWB thickness on solder joint temperature will be determined. It was concluded that this is a single cause and effect relationship that can safely be pulled out of the fractional factorial design.

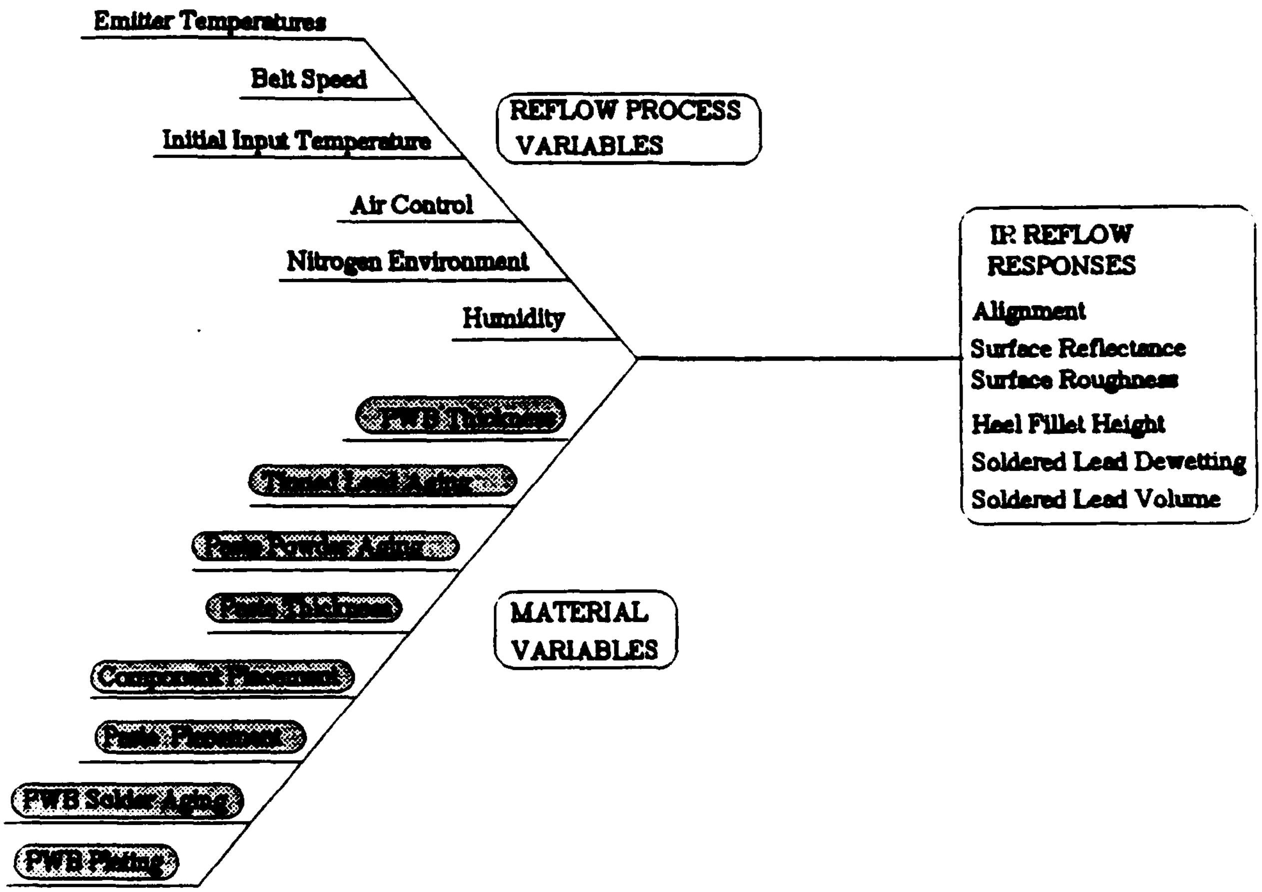


Figure 1. Infrared reflow cause and effect diagram.

Table 1. Process variable details.

Process Variable	Measuring Device/ Precision	Variable Range	Specification
**PWB thickness	Dial micrometer/ +/- 0.1-mil	58 to 68 mils	PWB fabrication drawing
Emitter temperatures	Panel thermocouples +/- 1 deg C	+/- 5 deg C from nominal	Baseline document
Belt speed	Stop watch and ruler/ +/- 0.01 ft per +/- 0.1 sec	22 to 26 in/min	Baseline document
Initial PWB temperature	Thermocouple/ +/- 1 deg C	10 to 30 deg C	Facility requirement
Exhaust air flow	Anemometer/ +/- 1 scfm	10 to 20 scfm	Baseline document
Nitrogen atmosphere	Oxygen analyzer	0 to 3% O_2	Baseline document
Humidity	Diaphragm gauge/ +/- 5%	35 to 65%	Baseline
**Tinned lead aging	Steam ager/ 1 minute	0 to 8 hours	Engineering judgment
**Solder paste aging	Oven with timer/ +/- 15 minutes	24 hours at 95 deg C	Engineering judgment
**Solder paste deposit thickness	Dial micrometer/ +/- 0.1-in	4/10-mil to 6/12-mil	Engineering judgment
**Component placement	Microscope with filar/ +/- 0.1-mil	+/- 2.5 mil from nominal	MIL-STD-2000
**Solder paste deposit placement	Microscope with filar/ +/- 0.1-mil	+/- 3.5 mils from nominal	MM 2-1

Table 1. Process variable details (concluded).

Process Variable	Measuring Device/ Precision	Variable Range	Specification
**PWB plating	Inspection/ +/- 0	Reflowed tin-lead and solder dipped/hot air leveled	TRW design options
**PWB plating aging	Steam ager/ +/- 1 minute	0 to six months	Engineering judgment

** Process variables being studied by this experiment.

Table 2. Response variable details.

Response Variable	Measuring Device/ Precision	Specification Limit	Specification
Lead/pad alignment	Microscope with filar +/- 0.1-mil	+/- 2.5 mils from nominal	MIL-STD-2000
Solder joint reflectance	Visual comparison/ NA	Flat (1) to specular (5)	Engineering judgment
Solder joint finish	Visual comparison/ NA	Smooth (1) to rough (5)	Engineering judgment
Solder heel fillet height	Microscope with filar/ +/- 0.1-mil	0 to 100% of "calf" length	MM 3-23
FPD soldered lead dewetting	Microscope with particle counting grid/NA	0 to 5% of soldered area	MM 3-22
FPD soldered lead solder volume	Visual comparison/ NA	No lead-to-pad fillet extending over top of lead foot and beyond edge	MM 3-21 and MM 3-22
Solder balls	Microscope with filar/ +/- 0.1-mil	0 to 5 mils	MM 5-6
Solder joint temperature	MOLE with thermocouple/ +/- 1 deg C	Nominal +/- 6 C	MIL-STD-2000

Table 3. Response table with interaction effects.

Random Order Trial Number	Standard Order Trial Number	Response Observed Value	A		B		C		AB		AC		BC		ABC	
			1	2	1	2	1	2	1	2	1	2	1	2	1	2
	1															
	2															
	3															
	4															
	5															
	6															
	7															
	8															
TOTAL																
NUMBER OF VALUES																
AVERAGE																
EFFECT																

II. MATERIALS AND SUPPLIES

PWB

Qty	P/N	Description
12	786582A	Nominal solder dipped and hot air leveled
12	786582C	Nominal fused tin-lead
1	786582G	Thin fused-tin lead
1	786582H	Thick fused-tin lead

Components

Qty	P/N	Description
78	PB-F86259	Kyocera, 132-pin, 25-mil pitch, leaded package
468	PB-C85124	20-pin, square, leadless chip carrier
260	PB-44823	28-pin, square, leadless chip carrier
208	IRK32F1-200B	32-pin, rectangular, leadless chip carrier
988	M55342K06B110BR	Chip resistor
1092	CDR02BX103BKURT	Chip capacitor
156	49BCP	Chip capacitor, CWR06 package style

Solder

QQ-S-571, Sn63, bar	
Metech RHF63, virgin	Metech, Inc. Route 401 Halverson, PA 19520
Metech RHF63, aged powder	Metech, Inc. Route 401 Halverson, PA 19520

Flux

Kester 1585-MIL	Kester Solder Co. 515 Touhy Ave Des Plaines, IL 60018-2575

Solvent

Blakosolv 404	Baron Blakeslee. Inc. 2001 N. Janice Avenue Melrose Park. IL 60160
Isopropyl alcohol	TT-I-335

Stencil

6/12 and 4/10 thicknesses	T-786582-6/1 top and T-786582-6/2 bottom

Miscellaneous

Palette knife. plastic	Holbein
Shamis. 99-150 cleaning cloth	Affiliated Manufacturers
Bristle brush	
Protective gloves. 96244	Jones Associates

III. TOOLS AND EQUIPMENT

General purpose stereo microscope. 0.7x-3x zoom with an American Optical No. 424. 10x-filar eyepiece.

Screen Printer No. 24-ASP	MPM Corp. 10 Forge Park Franklin. MA 02035
Malcom Viscometer	Austin American Technology 12201 Technology Blvd Austin. TX 78727
In-Line Cleaner. CBL-18	Baron-Blakeslee. Inc. 2001 N. Janice Ave. Melrose Park. IL 60160
Stencil Cleaner	Tooltronics. Inc. 710 Ivy Street Glendale. CA 91204
Microscan	CyberOptics Corp. 2331 University Ave.. SE

	Minneapolis, MN 55414
Robotic Workcell	Gelzer Systems 425 Enterprise Drive Westerville, OH 43081
Steam Aging Cabinet	Mountaingate Engineering 1510 Dell Ave. Campbell, CA 95008
Infrared Reflow Oven, Model SMD722	Vitronics Corp. Forbes Road Newmarket, NH 03857

IV. PROCEDURE

A. Eight Run Fractional Factorial Design

1. Select twelve 786582A PWBs and serialize them as ST1001 through ST1012.

2. Take SNs ST1007 through ST1012 from (1) above, and steam age for 8 hrs. Log and record the condition of the 786582A, SN ST1001 through ST1012 PWBs.

3. Select twelve 786582C PWBs and serialize them as ST1002 through ST1012.

4. Take SNs ST1007 thr4ough ST1012 from (3), above, and steam age for 8 hrs. Log and record the condition of the 786582C, SN ST1001 through ST1012 PWBs.

5. Create one worksheet, similar to the one shown in Table 3, for each of the six responses listed in Table 2 that are to be monitored. Column A is assigned to "Solder Paste Thickness," subcolumn 1 is for "Minimum Thickness," subcolumn 2 is for "Maximum Thickness." Column B is assigned to "Paste Powder Aging," subcolumn 1 is for "Unaged Powder," subcolumn 2 is for "Aged Powder." Column C is assigned to "Tinned Lead Aging," subcolumn 1 is for "Unaged," subcolumn 2 is for "Aged." Column AB is assigned to "Paste Deposit Registration," subcolumn 1 is for "0 mils," subcolumn 2 is for "+3.5 mils." Column AC is assigned to

"PWB Solder Aging," subcolumn 1 is for "Unaged," subcolumn 2 is for "Aged." Column BC is assigned to "Component Placement Registration," subcolumn 1 is for "0 mils," subcolumn 2 is for "+2.5 mils." Column ABC is assigned to "PWB Type," subcolumn 1 is for "Fused Tin-Lead," subcolumn 3 is for "Hot Air Leveled."

6. Randomize the "Standard Order Trial Number" column and enter the appropriate random number in the "Random Order Trial Number" column. Run the experimental trials using the random number sequence.

7. Clean the serialized PWBs in the in-line solvent cleaner.

8. Set up the 24-ASP stencil printer with an appropriate reference PWB. Keep in mind that an offset is being forced at this station (nom. and max. solder paste deposit misregistration). Also keep in mind that the thickness of the solder paste deposit is being forced at this station as well as the type of paste being printed.

9. Set up the component preparation and placement sides of the Gelzer robot. Keep in mind that an offset is being forced at this workcell (nom. and max. component misregistration). Also keep in mind that both "aged" and "unaged" FPDs are being "prepped" and placed at this workcell.

10. Set up the SMD 722 IR reflow oven with the appropriate thermal profile.

11. Set up the CBL-18 in-line cleaner with the appropriate cleaning process profile.

12. Select the stencil, PWB, solder paste, and component required for the run identified as random number 1.

12a. Stencil print the PWB forcing the desired offset.

12b. Measure and record the solder paste offset and the solder paste thickness.

12c. Place the printed PWB in the Gelzer robot load station and form, trim, tin, and place the selected FPD and all other components using the appropriate forced placement offset value.

12d. Measure and record the component placement offset.

12e. Reflow the PWB subassembly in the IR reflow oven and then clean it in the CBL-18 in-line cleaner.

13. Repeat steps (8) through (12), inclusive until all 8 experimental runs have been completed.

14. Swap the shaded cells between the '1' and '2' subcolumns of each of the 7 process variable columns (e.g., column A1 for runs 1-4 will be shaded rather than clear and column A2 for runs 5-8 will be shaded rather than clear).

Rerandomize the run order number and rerun the experimental matrix with the inverted process variable ranges. This will result in a reflected set of data which will isolate interaction effects that might mask the main effects of the process variables assigned to columns AB, AC, BC, and ABC.

B. Single Point Design

1. Select two 786582G PWBs and serialize them as ST1001 and ST1002.

2. Select two 786582H PWBs and serialize them as ST1001 and ST1002.

3. Set up the 24-ASP, stencil printer, the "prep" and place arms of the Gelzer robot, the SMD-722 IR reflow oven, and the CBL-18 in-line cleaner for nominal processing characteristics.

4. Select one 786582G and one 786582H PWBs and process through the line to yield two assembled and soldered PWBs.

5. Repeat (B.1) through (4). inclusive with the remaining PWBs.

V. RESPONSE DATA

A. Eight Run Fractional Factorial Design

1. Soldered Component Alignment

a. Measure the fine pitch component lead placement lateral misregistration for each of the 8 experimental runs at the locations listed in Table 4. Use a filar eyepiece on a microscope with a precision of at least 0.1-mil.

b. Measure the 20-pin LCC component termination placement lateral misregistration for each of the 8 experimental runs at the locations listed in Table 5. Use a filar eyepiece on a microscope with a precision of at least 0.1-mil.

c. Measure the 28-pin LCC component termination placement lateral misregistration for each of the 8 experimental runs at the locations listed in Table 6. Use a filar eyepiece on a microscope with a precision of at least 0.1-mil.

d. Measure the 32-pin LCC component termination placement lateral misregistration for each of the 8 experimental runs at the locations listed in Table 7. Use a filar eyepiece on a microscope with a precision of at least 0.1-mil.

e. Measure the chip component termination placement lateral and end-to-end misregistration for each of the 8 experimental runs at the locations listed in Table 8. Use a filar eyepiece on a microscope with a precision of at least 0.1-mil.

Table 4. Fine pitch device placement misregistration after solder.

Component	Pad		Lateral Displacement ΔX	ΔY
U1	130			
	131			
	132			
		avg	________	________
	1			
	2			
	3			
		avg	________	________
	64			
	65			
	66			
		avg	________	________
	67			
	68			
	69			
		avg	________	________
U20	130			
	131			
	132			
		avg	________	________
	1			
	2			
	3			
		avg	________	________
	64			

65
66

avg

Table 4. Fine pitch device placement misregistration after solder (concluded)

Component	Pad		Lateral Displacement ΔX	ΔY
	67			
	68			
	69			
		avg		
U39	130			
	131			
	132			
		avg		
	1			
	2			
	3			
		avg		
	64			
	65			
	66			
		avg		
	67			
	68			
	69			
		avg		

Table 5. 20-pin LCC device placement misregistration after solder.

Component	Pad		Lateral Displacement ΔX	ΔY
U2	1			
	2			
	3			
		avg		
	4			
	5			
	6			
		avg		
	11			
	12			
	13	avg		
	14			
	15			
	16	avg		
U5	1			
	2			
	3	avg		
	4			
	5			
	6	avg		

11
12
13 avg ________________

Table 5. 20-pin LCC device placement misregistration after solder.

Component	Pad		Lateral Displacement ΔX	ΔY
	14			
	15			
	16	avg		
U19	1			
	2			
	3	avg		
	4			
	5			
	6	avg		
	11			
	12			
	13	avg		
	14			
	15			
	16	avg		
U28	1			
	2			
	3	avg		
	4			

	5		
	6	avg	________________
—			
	11		
	12		
	13	avg	________________
—			

Table 5. 20-pin LCC device placement misregistration after solder (concluded)

Component	Pad		Lateral Displacement ΔX	ΔY
	14			
	15			
	16	avg	________	________
U33	1			
	2			
	3	avg	________	________
	4			
	5			
	6	avg	________	________
	11			
	12			
	13	avg	________	________
	14			
	15			
	16	avg	________	________

Table 6. 28-Pin LCC placement misregistration after solder.

Component	Pad		Lateral Displacement ΔX	ΔY
U22	2			
	3			
	4	avg	________	________
	5			
	6			
	7	avg	________	________
	16			
	17			
	18	avg	________	________
	19			
	20			
	21	avg	________	________
U31	2			
	3			
	4	avg	________	________
	5			
	6			
	7	avg	________	________
	16			

17
18 avg

Table 6. 28-Pin LCC placement misregistration after solder (concluded)

Component	Pad		Lateral Displacement ΔX	ΔY
	19			
	20			
	21	avg	________	________
U35	2			
	3			
	4	avg	________	________
	5			
	6			
	7	avg	________	________
	16			
	17			
	18	avg	________	________
	19			
	20			
	21	avg	________	________

Table 7. 32-pin LCC device placement misregistration after solder.

Component	Pad		Lateral Displacement ΔX	ΔY
U7	2			
	3			
	4	avg	____	____
	5			
	6			
	7	avg	____	____
	18			
	19			
	20	avg	____	____
	21			
	22			
	23	avg	____	____
U14	2			
	3			
	4	avg	____	____
	5			
	6			
	7	avg	____	____
	18			

19
20 avg

Table 7. 32-pin LCC device placement misregistration after solder (concluded)

Component	Pad		Lateral Displacement ΔX	ΔY
	21			
	22			
	23	avg	________	________
U34	2			
	3			
	4	avg	________	________
	5			
	6			
	7	avg	________	________
	18			
	19			
	20	avg	________	________
	21			
	22			
	23	avg	________	________

Table 8. Chip device placement misregistration after solder.

Component	Pad	Lateral ΔX	Lateral ΔY	Package Style
C43	1	______		CWR06
	2	______		
C46	1	______		CWR06
	2	______		
C48	1	______		CWR06
	2	______		
C2	1	______		CDR02
	2	______		
C7	1	______		CDR02
	2	______		
C26	1	______		CDR02
	2	______		
C36	1	______		CDR02
	2	______		
C42	1	______		CDR02
	2	______		
R1	1	______		M55342/6
	2	______		
R12	1	______		M55342/6
	2	______		
R30	1	______		M55342/6
	2	______		

Table 8. Chip device placement misregistration after solder (concluded)

Component	Pad	Lateral ΔX	ΔY	Package Style
R34	1	————		M55342/6
	2	————		
R25	1	————		M55342/6
	2	————		

IV. A. 2. **Reflowed Solder Joint Reflectance**

a. Visually examine the FPD lead solder joints for each of the eight runs at the locations listed in Table 9. and rate the reflectance of the joints by comparing them against the standard shown in Figure 2. Log and record the results.

b. Visually examine the 20-pin LCC solder joints for each of the eight runs at the locations listed in Table 10, and rate the reflectance of the joints by comparing them against the standard shown in Figure 2. Log and record the results.

c. Visually examine the 28-pin LCC solder joints for each of the eight runs at the locations listed in Table 11, and rate the reflectance of the joints by comparing them against the standard shown in Figure 2. Log and record the results.

d. Visually examine the 32-pin LCC solder joints for each of the eight runs at the locations listed in Table 12, and rate the reflectance of the joints by comparing them against the standard shown in Figure 2. Log and record the results.

e. Visually examine the chip component solder joints for each of the eight runs at the locations listed in Table 13 and rate the reflectance of the joints by comparing them against the standard shown in Figure 2. Log and record the results.

Table 9. Fine pitch device solder joint reflectance.

Component	Pad	Reflectance Rank (1-5)
U1	130	
	131	
	132	
		____________
	1	
	2	
	3	
		____________
	64	
	65	
	66	
		____________
	67	
	68	
	69	
		____________
U20	130	
	131	
	132	
		____________
	1	
	2	
	3	
		____________
	64	
	65	
	66	
		____________

Table 9. Fine pitch device solder joint reflectance (concluded)

Component	Pad	Reflectance Rank (1-5)
	67	
	68	
	69	
		____________
U39	130	
	131	
	132	
		____________
	1	
	2	
	3	
		____________
	64	
	65	
	66	
		____________
	67	
	68	
	69	
		____________

Table 10. 20-pin LCC device solder joint reflectance.

Component	Pad	Reflectance Rank (1-5)
U2	1	
	2	
	3	
		_____________
	4	
	5	
	6	
		_____________
	11	
	12	
	13	
		_____________
	14	
	15	
	16	
		_____________
U5	1	
	2	
	3	
		_____________
	4	
	5	
	6	
		_____________
	11	
	12	
	13	
		_____________
	14	
	15	
	16	
		_____________

Table 10. 20-pin LCC device solder joint reflectance (continued)

Component	Pad	Reflectance Rank (1-5)
U19	1	
	2	
	3	____________
	4	
	5	
	6	____________
	11	
	12	
	13	____________
	14	
	15	
	16	____________
U28	1	
	2	
	3	____________
	4	
	5	
	6	____________
	11	
	12	
	13	____________
	14	
	15	
	16	____________

Table 10. 20-pin LCC device solder joint reflectance (concluded)

Component	Pad	Reflectance Rank (1-5)
U33	1	
	2	
	3	____________
	4	
	5	
	6	____________
	11	
	12	
	13	____________
	14	
	15	
	16	____________

Table 11. 28-pin LCC device solder joint reflectance.

Component	Pad	Reflectance Rank (1-5)
U22	2	
	3	
	4	____________
	5	
	6	
	7	____________
	16	
	17	
	18	____________
	19	
	20	
	21	____________
U31	2	
	3	
	4	____________
	5	
	6	
	7	____________
	16	
	17	
	18	____________
	19	
	20	
	21	____________

Table 11. 28-pin LCC device solder joint reflectance (concluded)

Component	Pad	Reflectance Rank (1-5)
U35	2	
	3	
	4	______________
	5	
	6	
	7	______________
	16	
	17	
	18	______________
	19	
	20	
	21	______________

Table 12. 32-pin LCC device solder joint reflectance.

Component	Pad	Reflectance Rank (1-5)
U7	2	
	3	
	4	____________
	5	
	6	
	7	____________
	18	
	19	
	20	____________
	21	
	22	
	23	____________
U14	2	
	3	
	4	____________
	5	
	6	
	7	____________
	18	
	19	
	20	____________
	21	
	22	
	23	____________

Table 12. 32-pin LCC device solder joint reflectance (concluded)

Component	Pad	Reflectance Rank (1-5)
U34	2	
	3	
	4	____________
	5	
	6	
	7	____________
	18	
	19	
	20	____________
	21	
	22	
	23	____________

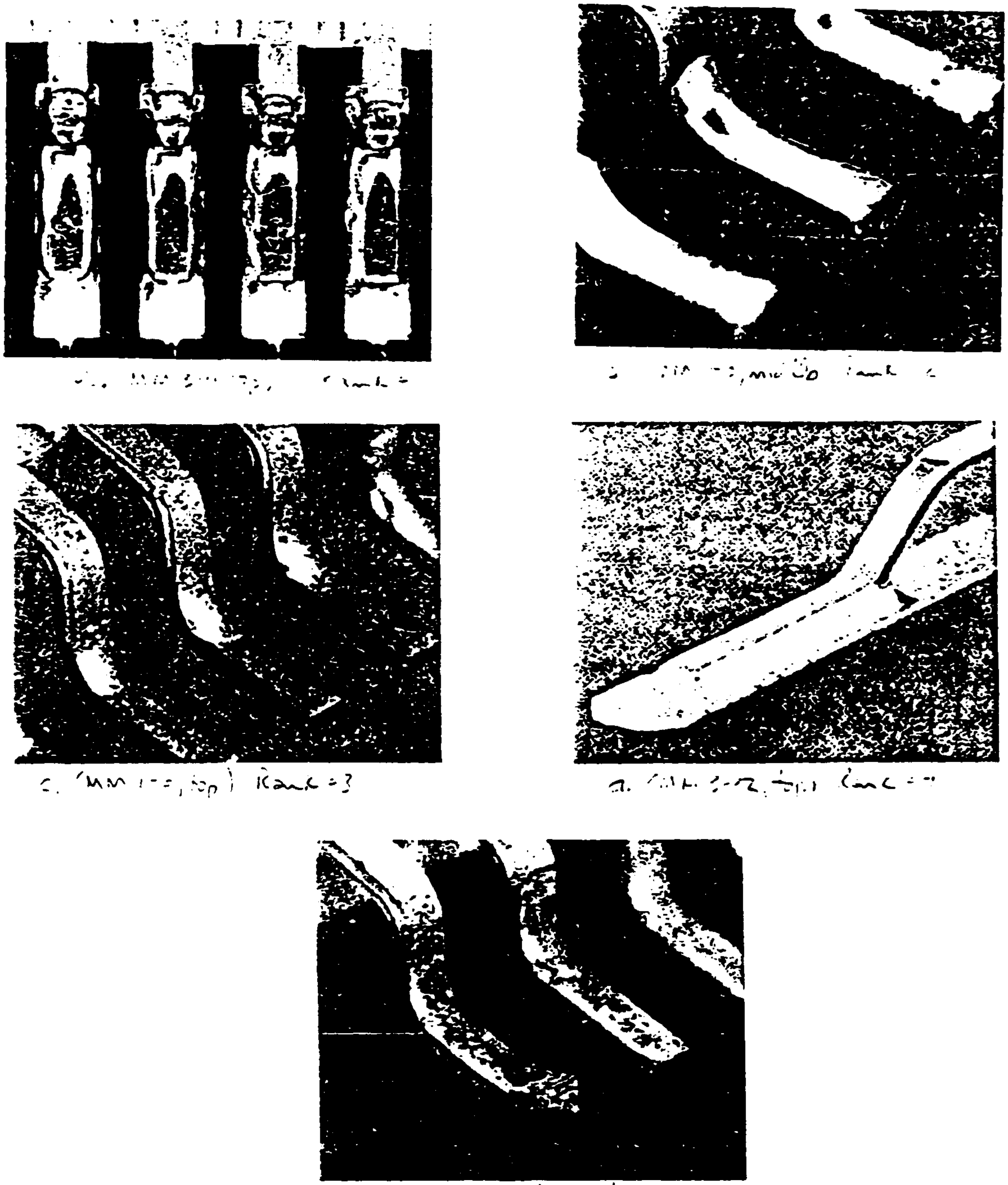
Table 13. Chip device solder joint reflectance.

Component	Pad	Reflectance Rank (1-5)	Package Style
C43	1	___________	CWR06
	2	___________	
C46	1	___________	CWR06
	2	___________	
C48	1	___________	CWR06
	2	___________	
C2	1	___________	CDR02
	2	___________	
C7	1	___________	CDR02
	2	___________	
C26	1	___________	CDR02
	2	___________	
C36	1	___________	CDR02
	2	___________	
C42	1	___________	CDR02
	2	___________	
R1	1	___________	M55342/6
	2	___________	
R12	1	___________	M55342/6
	2	___________	

Table 13. Chip device solder joint reflectance (concluded)

Component	Pad	Reflectance Rank (1-5)	Package Style
R30	1	___________	M55342/6
	2	___________	
R34	1	___________	M55342/6
	2	___________	
R25	1	___________	M55342/6
	2	___________	

MAGNIFICATION 30X



[illegible]

[illegible]

c. (MM 1-5, top) Rank = 3

d. (MM 3-2, top) Rank = [illegible]

e. (MM 1-11, bottom) Rank = [illegible]

Figure 2. Reflowed solder joint reflectance.

V. A. 3. Reflowed Solder Joint Roughness

a. Visually examine the FPD lead solder joints for each of the eight runs at the locations listed in Table 14 and rate the roughness of the joints by comparing them against the standard shown in Figure 3. Log and record the results.

b. Visually examine the 20-pin LCC solder joints for each of the eight runs at the locations listed in Table 15. and rate the roughness of the joints by comparing them against the standard shown in Figure 3. Log and record the results.

c. Visually examine the 28-pin LCC solder joints for each of the eight runs at the locations listed in Table 16 and rate the roughness of the joints by comparing them against the standard shown in Figure 3. Log and record the results.

d. Visually examine the 32-pin LCC solder joints for each of the eight runs at the locations listed in Table 17 and rate the roughness of the joints by comparing them against the standard shown in Figure 3. Log and record the results.

e. Visually examine the chip component solder joints for each of the eight runs at the locations listed in Table 18 and rate the roughness of the joints by comparing them against the standard shown in Figure 3. Log and record the results.

Table 14. Fine pitch device solder joint roughness.

Component	Pad	Roughness Rank (1-5)
U1	130	
	131	
	132	
		___________
	1	
	2	
	3	
		___________
	64	
	65	
	66	
		___________
	67	
	68	
	69	
		___________
U20	130	
	131	
	132	
		___________
	1	
	2	
	3	
		___________
	64	
	65	
	66	
		___________
	67	
	68	
	69	
		___________

Table 14. Fine pitch device solder joint roughness (concluded)

Component	Pad	Roughness Rank (1-5)
U39	130	
	131	
	132	
		___________
	1	
	2	
	3	
		___________
	64	
	65	
	66	
		___________
	67	
	68	
	69	
		___________

Table 15. 20-pin LCC solder joint roughness.

Component	Pad	Roughness Rank (1-5)
U2	1	
	2	
	3	----------
	4	
	5	
	6	----------
	11	
	12	
	13	----------
	14	
	15	
	16	----------
U5	1	
	2	
	3	----------
	4	
	5	
	6	----------
	11	
	12	
	13	----------
	14	
	15	
	16	----------

Table 15. 20-pin LCC solder joint roughness (continued)

Component	Pad	Roughness Rank (1-5)
U19	1	
	2	
	3	-----------
	4	
	5	
	6	-----------
	11	
	12	
	13	-----------
	14	
	15	
	16	-----------
U28	1	
	2	
	3	-----------
	4	
	5	
	6	-----------
	11	
	12	
	13	-----------
	14	
	15	
	16	-----------
U33	1	
	2	
	3	-----------

Table 15. 20-pin LCC solder joint roughness (concluded)

Component	Pad	Roughness Rank (1-5)
	4	
	5	
	6	
		___________
	11	
	12	
	13	
		___________
	14	
	15	
	16	
		___________

Table 16. 28-pin LCC device solder joint roughness.

Component	Pad	Roughness Rank (1-5)
U22	2	
	3	
	4	___________
	5	
	6	
	7	___________
	16	
	17	
	18	___________
	19	
	20	
	21	___________
U31	2	
	3	
	4	___________
	5	
	6	
	7	___________
	16	
	17	
	18	___________
	19	
	20	
	21	___________

Table 16. 28-pin LCC device solder joint roughness (concluded)

Component	Pad	Roughness Rank (1-5)
U35	2	
	3	
	4	
		___________
	5	
	6	
	7	
		___________
	16	
	17	
	18	
		___________
	19	
	20	
	21	
		___________

Table 17. 32-pin LCC device solder joint roughness.

Component	Pad	Roughness Rank (1-5)
U7	2 3 4	___________
	5 6 7	___________
	18 19 20	___________
	21 22 23	___________
U14	2 3 4	___________
	5 6 7	___________
	18 19 20	___________
	21 22 23	___________

Table 17. 32-pin LCC device solder joint roughness (concluded)

Component	Pad	Roughness Rank (1-5)
U34	2	
	3	
	4	

	5	
	6	
	7	

	18	
	19	
	20	

	21	
	22	
	23	

Table 18. Chip device solder joint roughness.

Component	Pad	Roughness Rank (1-5)	Package Style
C43	1	___________	CWR06
	2	___________	
C46	1	___________	CWR06
	2	___________	
C48	1	___________	CWR06
	2	___________	
C2	1	___________	CDR02
	2	___________	
C7	1	___________	CDR02
	2	___________	
C26	1	___________	CDR02
	2	___________	
C36	1	___________	CDR02
	2	___________	
C42	1	___________	CDR02
	2	___________	
R1	1	___________	M55342/6
	2	___________	
R12	1	___________	M55342/6
	2	___________	
R30	1	___________	M55342/6
	2	___________	

Table 18. Chip device solder joint roughness (concluded)

Component	Pad	Roughness Rank (1-5)	Package Style
R34	1	____________	M55342/6
	2	____________	
R25	1	____________	M55342/6
	2	____________	

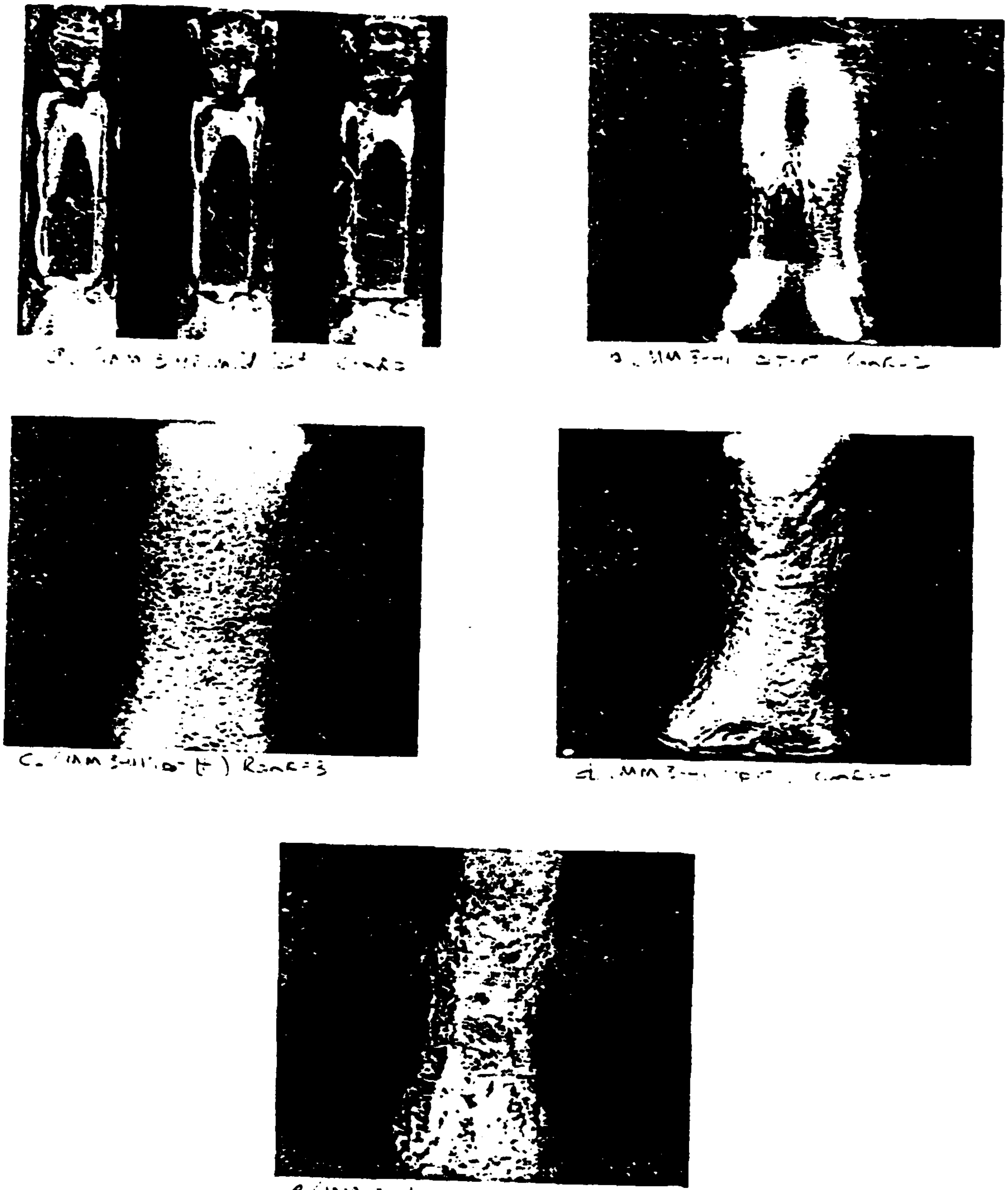


Figure 3. Reflowed solder joint roughness.

IV. A. 4. FPD Solder Joint Heel Fillet Height

a. Measure the length of reflowed solder paste wetting along the "calf" of the FPD lead and report the result as a percent of the total length of the "calf". Make these measurements at the locations listed in Table 19. Log and record the results.

5. FPD Soldered Lead Dewetting

a. Examine the solder joints of the leads of the FPD packages at 10x and map non-wet areas onto a grid. This grid will enable a measurement of the percent of the soldered area of a lead that is non-wet. This mapping shall be accomplished on five leads on each side of each FPD package. These lead numbers are 1, 9, 17, 25, 33, 34, 42, 50, 58, 66, 67, 75, 83, 91, 99, 100, 108, 116, 124, and 132. Log and record the results.

6. FPD Soldered Lead Soldered Volume

a. Examine the solder joints of the leads of the FPD packages at 10x and rate the volume of the solder in the solder joints by comparing them against the standards shown in Figure 4. Examine the following leads on all FPD packages on the PWB under test: 1, 9, 17, 25, 33, 34, 42, 50, 58, 66, 67, 75, 83, 91, 99, 100, 108, 116, 124, and 132. Log and record the results.

7. Solder Balls

a. Transmission x-ray and visually examine the assembled PWB (PWA) after in-line cleaning, and locate the largest solder ball. If the solder ball is located under a package, remove the package, and measure the diameter of the solder ball using a microscope with a filar eyepiece.

Table 19. Fine pitch device soldered lead heel fillet.

Component	Pad	Heel Fillet Height
U1	130	
	131	
	132	

	1	
	2	
	3	

	64	
	65	
	6	

	67	
	68	
	69	

U20	130	
	131	
	132	

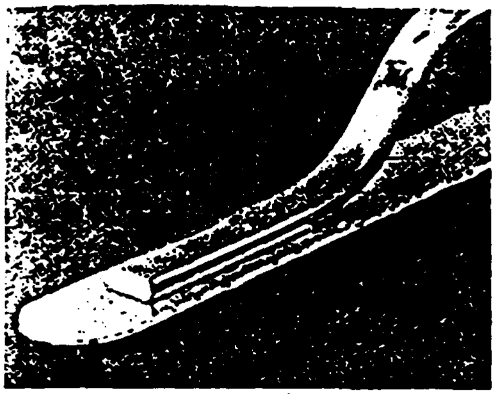
	1	
	2	
	3	

	64	
	65	
	66	

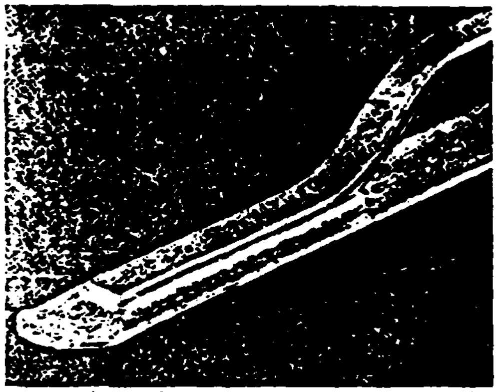
	67	
	68	
	69	

Table 19. Fine pitch device soldered lead heel fillet (concluded)

Component	Pad	Heel Fillet Height
U39	130	
	131	
	132	
		__________
	1	
	2	
	3	
		__________
	64	
	65	
	66	
		__________
	67	
	68	
	69	
		__________

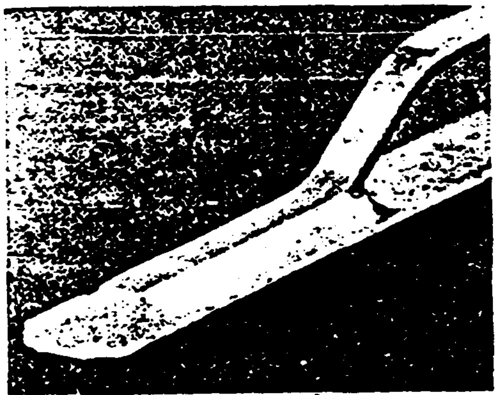


a. (MM 3-21, 10 ... Rank=1

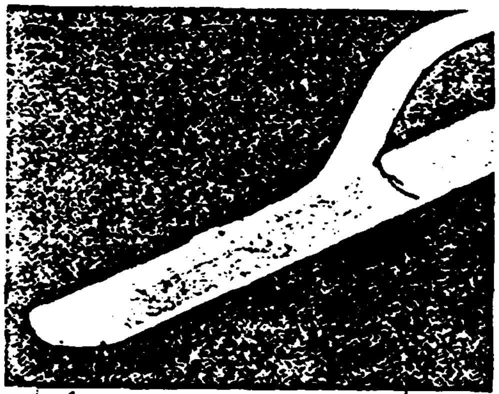


b. MM 3-2 ... Rank=2

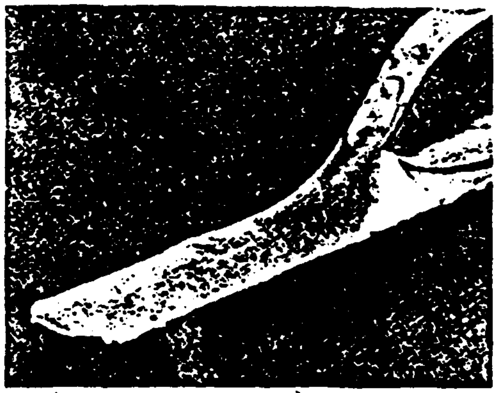
MAGNIFICATION 8X



c. (MM 3-21, ... Rank=3



d. (MM 3-2?, ... Rank=4



e. MM 3-2?, ... Rank=5

Figure 4. Reflowed solder joint volume.

V. A. 7. a. (cont'd)

If the solder ball is not hidden from view. use the microscope with the filar-eyepiece to measure the diameter of the solder ball directly. Log and record the results.

B. Single Point Design

1. Solder Joint Temperature

a. Mount five thermocouples on each PWB on the solder joints at UL-1. U20-1. U39-67. U5-4 and U25-18.

b. Connect the thermocouple to the MOLE and run the PWBs through the IR reflow oven. Log and record the temperature profiles.

VI. DATA REDUCTION

Using the data gathered by this experiment. the response sheets typified by Table 3 will be completed for each response; and significant interstation process variables will be identified.

Additional statistical analyses of the data using analysis of variance (ANOVA) techniques will yield variability. experimental error. and process capability indices data.

Interoffice Correspondence
TRW Avionics & Surveillance Group

91.Q602.PCC.ST2.0

Subject	Date	From
Detailed Experimental Plan FPD Lead Tinning (ST20)	12 February 1991	T. NEILLO
To	**cc**	**Location/Phone**
P. Glaser	D. Cavanaugh P. Finkenbinder J. Murray P. Crepeau	RC4/1073/3605

SUBTASK 2

FINE PITCH DEVICE LEAD TINNING

This document presents the detailed experimental plan and procedures for performing the Sub Task 2 experimental procedure. This experiment is designed to identify significant inter-workstation process variables that affect several responses for the fine pitch device (FPD) lead tinning work cell. The significant process variables were identified in a "brainstorming" session among several manufacturing and process engineers. Figure 1 presents a cause and effect diagram that identifies the process variables and responses for the FPD lead tinning work cell. Those process variables that are being evaluated in this experiment have been encircled. The process variables that are not encircled are intrastation variables that were previously evaluated and reported.

Ranges (or levels) for the process variables were selected based on tolerances that were expected to be encountered on the factory floor. These ranges, the instruments used to measure the variables, and the reference to the source for the ranges are presented in Table 1. Double asterisks identify those process variables being evaluated by this experiment. Responses to be analyzed for the FDP lead tinning workstation, the instruments used to measure the responses, the specification limits for the responses, and the source for the specification limits are presented in Table 2. This experimental design is a full factorial with three variables. No reflection is required. One replicate will be run, however.

Table 3 presents the form that will be used for each response evaluated by this experimental design. Columns AB, AC, BC, and ABC will be used for experimental error measurements.

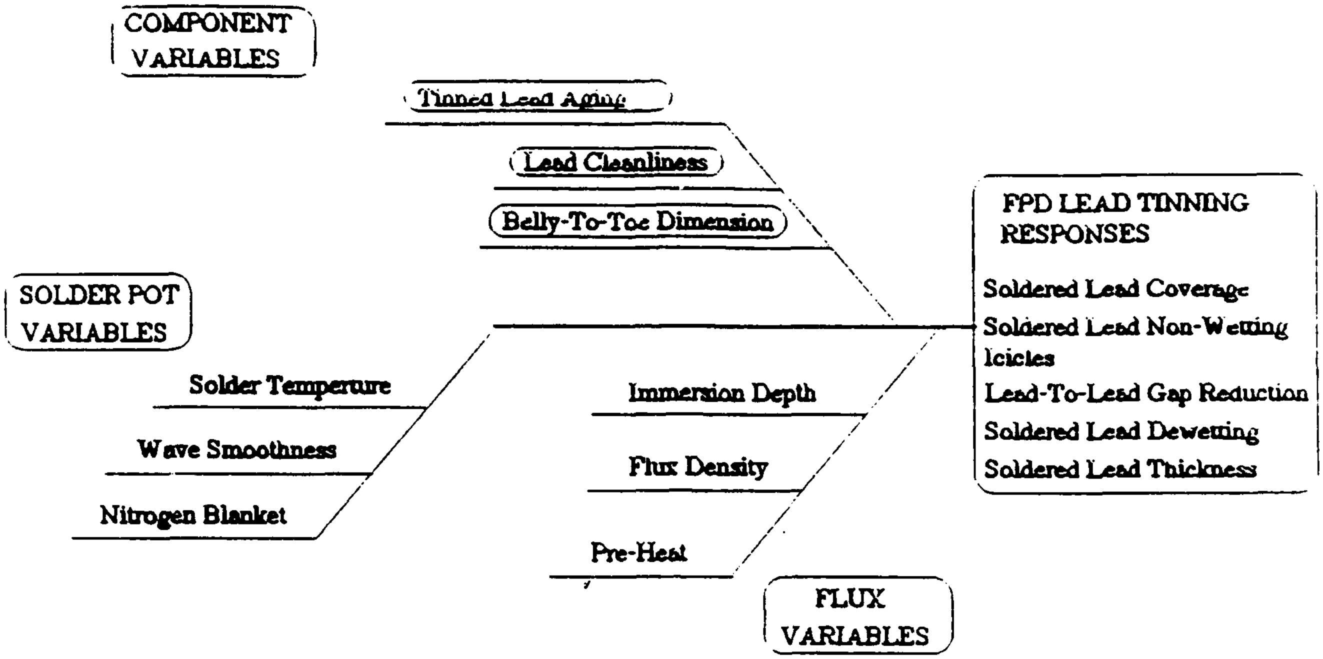


Figure 1. FPD component tinning cause and effect diagram.

Table 1. Process variable details.

Process Variable	Measuring Device/ Precision	Variable Range	Specification
**Lead aging	Steam aging cabinet/ +/- 1 minute	0 to 8 hours (0 to 12 mos.)	Engineering judgment
**Lead cleanliness	10% soln. of oil/ +/- 1%	Clean to contaminated	Engineering judgment
**Belly-to-toe dimension	Microscan/ +/- 0.15 mil	4 to 12 mils	TRW cleaning study
"Calf" immersion in flux	Microscope with filar/ +/- 0.2-mil	0 to 100%	Baseline document
Flux density	Sensby sp gr system/ +/- 0.001	0.885 to 0.895	Baseline document
Solder temperature	Robot controller/ +/- 1 deg F	490 to 510 deg F	MIL-STD-2000
Wave smoothness	Visual	0 to minor turbulence	Baseline document
Nitrogen flow	Flow meter +/- 1 scfh	0 to 100 scfh	Baseline document

Table 2. Response variable details.

Response Variable	Measuring Device/ Precision	Specification Limit	Specification
Solder coverage at "calf"	Microscope with filar/ +/- 0.2-mil	25% to 100% of lead below knee (none at knee bend)	MM 1-6, 1-7
Solder thickness at mid- "calf"	Microscope with filar/ +/- 0.2-mil (cross section)	0.1 to 1 mil	Engineering judgment
Non-wet solder surface	Microscope with particle counting grid/NA	0 to 5% of area	MM 1-9
De-wet solder surface	Microscope with particle counting grid/NA	0 to 5% of area	MM 1-9
Icicles	Microscope with filar/ +/- 0.2-mil	0 to 10 mils	MM 1-9
Lead-to-lead gap reduction	Microscope with filar/ +/- 0.2-mil	0 to 10 mils	Engineering judgment

Table 3. Response table with interaction effects.

Random Order (Trial Number)	Standard Order (Trial Number)	Response Observed Values	A		B		C		AB		AC		BC		ABC	
			1	2	1	2	1	2	1	2	1	2	1	2	1	2
	1															
	2															
	3															
	4															
	5															
	6															
	7															
	8															
TOTAL																
NUMBER OF VALUES																
AVERAGE																
EFFECT																

Serial number/Process Variable Relationship Matrix

	Belly-to-Toe Dimension		Lead Aging (Steam Aged)		Lead Cleanliness		Run Number	
Serial Number	4 mils	12 mils	0	12 mos.	Clean	Contam.	Initial	Replicat.
KYO ST2001	XX		XX		XX		1	
KYO ST2002	XX		XX		XX			1
KYO ST2003	XX		XX			XX	2	
KYO ST2004	XX		XX			XX		2
KYO ST2005	XX			XX	XX		3	
KYO ST2006	XX			XX	XX			3
KYO ST2007	XX			XX		XX	4	
KYO ST2008	XX			XX		XX		4
KYO ST2009		XX	XX		XX		5	
KYO ST2010		XX	XX		XX			5
KYO ST2011		XX	XX			XX	6	
KYO ST2012		XX	XX			XX		6
KYO ST2013		XX		XX	XX		7	
KYO ST2014		XX		XX	XX			7
KYO ST2015		XX		XX		XX	8	
KYO ST2016		XX		XX		XX		8

Figure 2

Robotic Workcell, [response name] experimental design matrix

Initial Run

Random Sequence Number	Run Number	Proposed/Actual Variable States: Belly-to-Toe Dimension Prop.	Belly-to-Toe Dimension Act.	Lead Aging Prop.	Lead Aging Act.	Lead Cleanliness Prop.	Lead Cleanliness Act.	EXPERIMENTAL ERROR	
7	KYO 1 ST2001	4 mils		0		Clean			
2	KYO 2 ST2003	4 mils		0		Cont.			
5	KYO 3 ST2005	4 mils		12 mos		Clean			
6	KYO 4 ST2007	4 mils		12 mos		Cont.			
4	KYOC 5 ST2009	12 mils		0		Clean			
8	KYOC 6 ST2011	12 mils		0		Cont			
3	KYOC 7 ST2013	12 mils		12 mos		Clean			
1	KYOC 8 ST2015	12 mils		12 mos		Cont			

Figure 3

Robotic Workcell, [response name] experimental design matrix

Replication

Random Sequence Number	Run Number	Proposed/Actual Variable States: Belly-10-Toe Dimension Prop.	Belly-10-Toe Dimension Act.	Lead Aging Prop.	Lead Aging Act.	Lead Cleanliness Prop.	Lead Cleanliness Act.	EXPERIMENTAL ERROR	
5	KYO 1 ST2002	4 mils		0		Clean			
1	KYO 2 ST2004	4 mils		0		Cont.			
2	KYO 3 ST2006	4 mils		12 mos		Clean			
4	KYO 4 ST2008	4 mils		12 mos		Cont			
6	KYOC 5 ST2010	12 mils		0		Clean			
3	KYOC 6 ST2012	12 mils		0		Cont			
8	KYOC 7 ST2014	12 mils		12 mos		Clean			
7	KYOC 8 ST2016	12 mils		12 mos		Cont.			

Figure 4

II. MATERIALS AND SUPPLIES

PWB - (None required)

Components

Qty	P/N	Description
16	PB-F86259	Kyocera, 25 mil pitch, 132 lead chip carrier.

Solder

QQ-S-571, Sn63, bar	Virgin Alloy

Flux

Kester 185	Kester Solder Co. 515 Touhy Ave Des Plaines, IL 60018-2575

Stencil - (None required)

Miscellaneous

96244 Protective gloves	Jones Associates
Machine Cutting Oil	Oil, petroleum, for contaminating leads

Solvent

Genosolv DMSA	Baron Blakeslee, Inc. 2001 N. Janice Avenue Melrose Park, IL 60160
Isopropyl Alcohol	TT-I-735

III. TOOLS AND EQUIPMENT

General purpose stereo microscope, 0.7x-3x zoom with an American Optical No. 424, 10x-filar eyepiece.

Dial Micrometer, Lufkin

Polaroid camera with macrolens (to assist in evaluation of solderability).

Steam Aging Cabinet	Mountain Gate Engineering 1510 Dell Ave. Campbell, CA 95008
Robotic Workcell, Model 1312	Gelzer Systems 425 Enterprise Drive Westerville, OH 43081

IV. PROCEDURE

NOTE: **Refer to the "SERIAL NUMBER/PROCESS VARIABLE RELATIONSHIP MATRIX" (see figure #2) when serializing the FPD packages to determine which variables are forced for each serial number.**

1. Select sixteen Kyocera, 132-pin fine pitch device (#PB-F86259) packages and place a black ink dot on the lid of all sixteen packages to indicate pin #1 (see figure #5). Serialize them as KYO ST2001 through -016.

2. Locate the following eight FPD package serial numbers and form their leads to the minimum "belly-to-toe" dimensions (4 mils). Log and record the serial numbers of these packages and their initial belly-to-toe measurements in table 4.

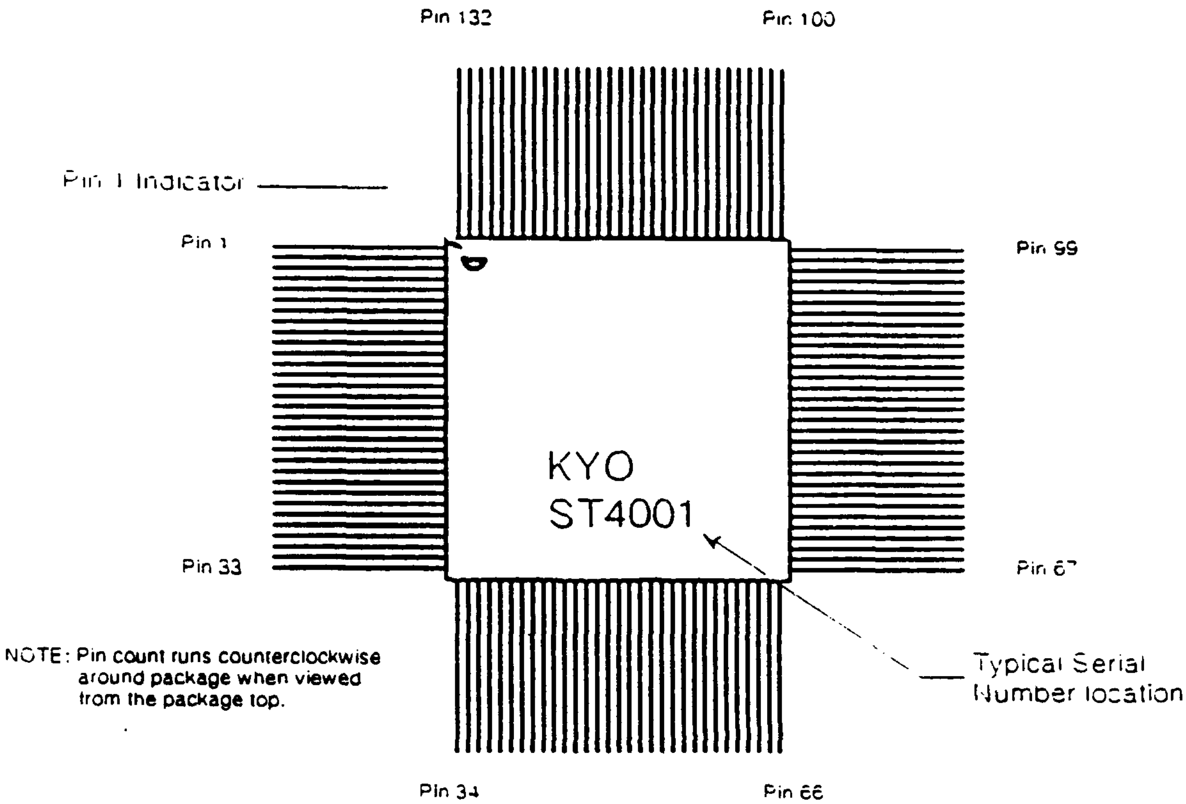


FIGURE #5

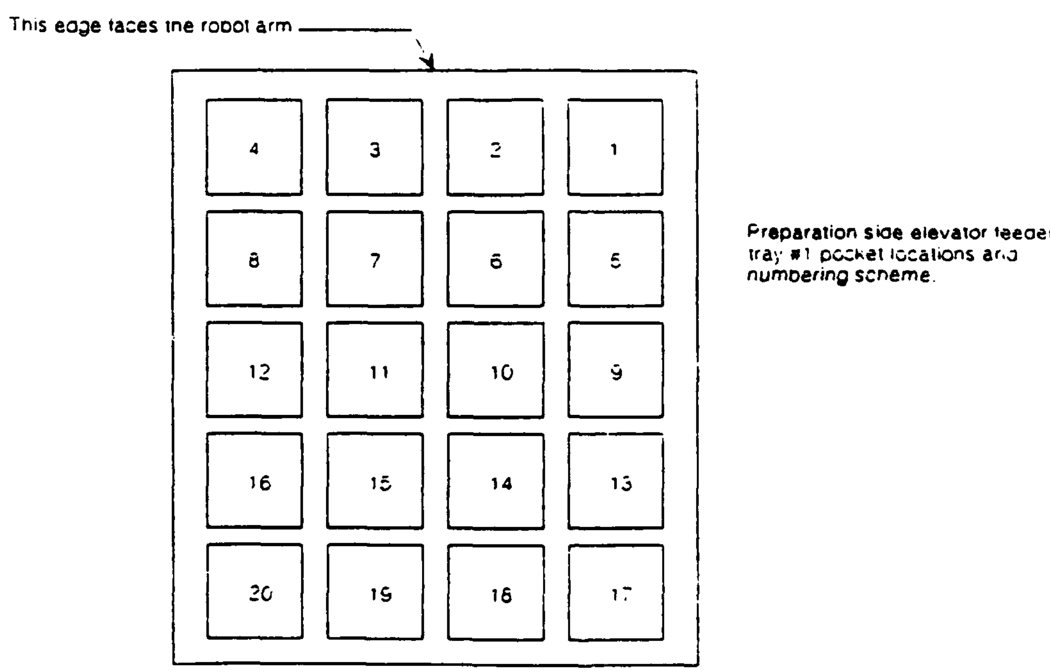


FIGURE #6

FPD Serial Numbers

KYO ST2001	KYO ST2005
KYO ST2002	KYO ST2006
KYO ST2003	KYO ST2007
KYO ST2004	KYO ST2008

3. Locate the following eight FPD package serial numbers and form their leads to the maximum "belly-to-toe" dimensions (12 mils). Log and record the serial numbers of these packages and their initial belly-to-toe measurements in table 4.

FPD Serial Numbers

KYO ST2009	KYO ST2013
KYO ST2010	KYO ST2014
KYO ST2011	KYO ST2015
KYO ST2012	KYO ST2016

4. Locate the following eight FPD package serial numbers and subject them to the steam aging process for a period of eight (8) hours.

FPD Serial Numbers

KYO ST2005	KYO ST2013
KYO ST2006	KYO ST2014
KYO ST2007	KYO ST2015
KYO ST2008	KYO ST2016

5. Prepare the lead contaminating solution by adding 10 ml of machine cutting oil (or equivalent) to 90 ml of isopropyl alcohol. Stir this solution gently until it appears to be homogeneous. Cover the solution tightly until needed.

6. Locate the following eight FPD package serial numbers and dip their leads into the contaminating solution up to the top of the lead knee. Remove the excess contaminant by placing the soiled devices on a soft lint free absorbant wipe supported underneath by flat firm surface.

<u>FPD Serial Numbers</u>

KYO ST2003	KYO ST2011
KYO ST2004	KYO ST2012
KYO ST2007	KYO ST2015
KYO ST2008	KYO ST2016

7. Create one worksheet, similar to the one shown in Table 3, for each of the six responses listed in Table 2 that are to be monitored (see figures #3 & #4). Column A is assigned to "belly-to-toe" dimension; subcolumn 1 is for minimum length; subcolumn 2 is for maximum length. Column B is assigned to "lead aging;" subcolumn 1 is for the as received condition; *subcolumn 2 is for the aged condition.* Column C is assigned to "lead cleanliness;" subcolumn 1 is for the uncontaminated condition; subcolumn 2 is for the contaminated condition. The remaining columns are for experimental error determinations.

8. . Run the experiment trials using the random number sequence as listed in Figure 3, 'Random Sequence Number' column.

9. Set up the component preparation side of the Gelzer robotic workcell minus the part forming function and load the tinning program "**TIN.BBF**."

10. Place the appropriate 132-pin FPD packages into the preparation elevator tray #1 in accordance with the **random sequence order number** and starting with pocket #1 (see figure #6). With the feeder tray oriented as shown in figure 6, place the pin #1 indicator of each FPD in the upper left hand corner of the feeder pockets. Tin, clean and inspect the leads of the first two (2) or three (3) devices.

11. Take some preliminary measurements to confirm that no other significant variables are affecting the process. Stop and contact the cognizant engineer if there appears to be any undocumented outside influences in the process.

12. Complete the balance of the initial experimental run as directed by the specific response worksheets.

13. Rerun the experimental matrix using the random number sequence as listed in Figure 4, 'Random Sequence Number' column. This will result in a replicate set of data to aid in statistical analyses of the experiment.

V. RESPONSE DATA

A. Solder Coverage

1. The solder coverage shall be quantified as a percentage of lead solder wetting where 100% coverage is defined as solder wetting up to, but not into, the lead knee. Use a microscope to make these measurements and enter this data into table #5. The leads designated for data collection and the measurement conventions are delineated in table #5.

B. Non-Wet Solder Surface

1. Examine the soldered lead surfaces of the formed and tinned FPD packages for evidence of solder non-wetting. Map any non-wet areas onto a grid and record this information as prompted in table #6. The grid will enable a measurement of the percent of the tinned area of a lead that is non-wet.

C. Dewetted Solder Surface

1. Examine the soldered lead surfaces of the formed and tinned FPD packages for evidence of solder dewetting. Map any dewetted areas onto a grid and record this information as prompted in table #7. The grid will enable a measurement of the percent of the tinned area of a lead that is dewetted.

D. Icicles

1. Visually scan the formed and tinned leads of each FPD package for evidence of icicling. Count the total number of icicles encountered for each side of the FPD package and record this information in table #8. Identify the lead that represents the worst case of icicling for each side of the package. Use a filar eyepiece on a microscope to measure the length of that worst case icicle to a precision of 0.2-mil. maximum and record this information in table #8.

NOTE: **Do not confuse icicling with toe burrs. An icicle is formed purely from the solder on the lead. Contact the cognizant engineer for clarification if any doubt exist as to whether a suspected icicle is truly that or a toe burr (See table #8).**

E. Lead-to-Lead Gap Reduction

1. Visually scan the formed and tinned leads of each FPD package for evidence of lead-to-lead gap reduction. Identify all lead-to-lead gap spaces that are 5 mils or less and record the number of occurrence for each side of the FPD package as prompted by table #9. Identify the lead-to-lead gap that represents the worst case of gap reduction due to solder for each side of the FPD package and record this data in table #9. The measurement convention is delineated in a diagram located with this table. Use a filar eyepiece on a microscope to measure that worst case gap reduction to a precision of 0.2-mil, maximum.

F. Solder Thickness at Calf

1. After all other response data have been gathered, microsection the leads of the FPD packages and measure the thickness of the solder at the mid-"calf" sections of the formed and tinned leads on each side of each package. The specific leads to be measured are delineated in table #10. Record all pertinent data in this table. The average thickness of the solder coating shall be calculated in accordance with the diagram located with table #10.

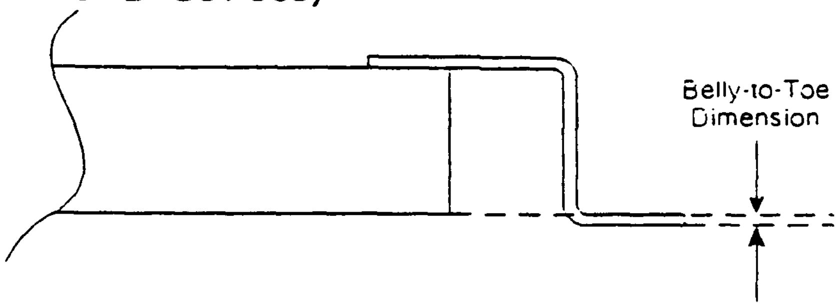
I. DATA REDUCTION

Using the data gathered by this experiment, the response sheets typified by Table 3 will be completed for each response; and significant interstation process variables will be identified.

Additional statistical analyses of the data using analysis of variance (ANOVA) techniques will yield variability, experimental error, and process capability indices data.

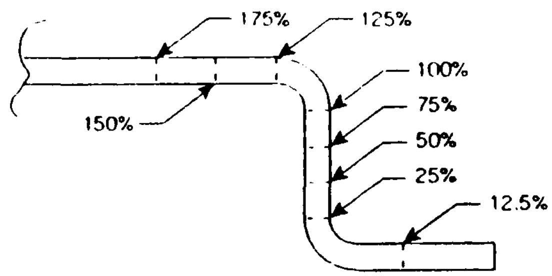
Table #4

Initial Belly-to-Toe data collection sheet
(Use one sheet for all devices)



	Avg Belly-to-Toe Dimension				Avg Dim of
Serial Number	Side 1	Side 2	Side 3	Side 4	All Four Sides
KYO ST2001					
KYO ST2002					
KYO ST2003					
KYO ST2004					
KYO ST2005					
KYO ST2006					
KYO ST2007					
KYO ST2008					
KYO ST2009					
KYO ST2010					
KYO ST2011					
KYO ST2012					
KYO ST2013					
KYO ST2014					
KYO ST2015					
KYO ST2016					

Table #5



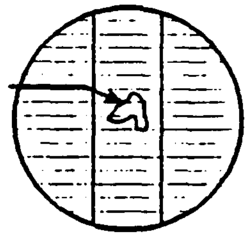
Solder Coverage data collection sheet

(One sheet for each device)

Device serial number ______________

Side	Lead Numbers (Measure these leads as indicated above)
1	01___ 02___ 03___ avg___ 16___ 17___ 18___ avg___ 31___ 32___ 33___ avg___
2	34___ 35___ 36___ avg___ 49___ 50___ 51___ avg___ 64___ 65___ 66___ avg___
3	67___ 68___ 69___ avg___ 82___ 83___ 84___ avg___ 97___ 98___ 99___ avg___
4	100___ 101___ 102___ avg___ 115___ 116___ 117___ avg___ 130___ 131___ 132___ avg___

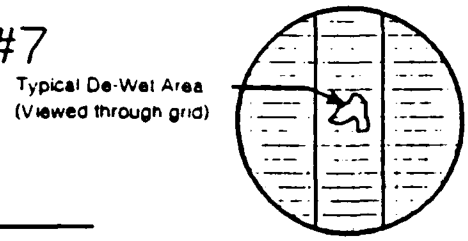
Table #6



Non-Wetting data collection sheet
(One sheet for each device)
Device serial number________________

	Side 1		Side 2		Side 3		Side 4	
#	Lead Number	% Non-wet	Lead Number	% Non-wet	Lead Number	% Non-wet	Lead Number	% Non-wet
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								
33								

Table #7



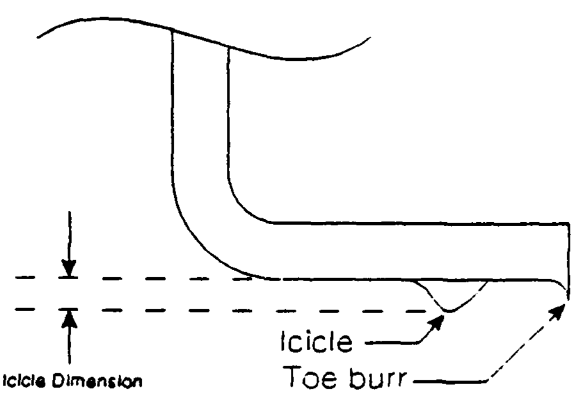
De-Wetting data collection sheet
(One sheet for each device)
Device serial number________________

	Side 1		Side 2		Side 3		Side 4	
#	Lead Number	% De-wet	Lead Number	% De-wet	Lead Number	% De-wet	Lead Number	% De-wet
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								
32								
33								

Table #8

Icicle data collection sheet
(Use one sheet for all devices)

Measurements are to be in mils
(Thousandths of an inch)

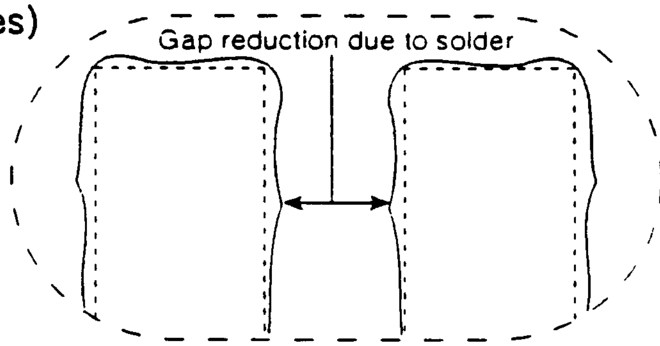


	Icicle Count and Worst Case Dimension								Worst Case Icicle For All 4 Sides
	Side 1		Side 2		Side 3		Side 4		
Serial Number	Icicle Count	[illegible]	Icicle Count	[illegible]	Icicle Count	[illegible]	Icicle Count	[illegible]	
KYO ST2001									
KYO ST2002									
KYO ST2003									
KYO ST2004									
KYO ST2005									
KYO ST2006									
KYO ST2007									
KYO ST2008									
KYO ST2009									
KYO ST2010									
KYO ST2011									
KYO ST2012									
KYO ST2013									
KYO ST2014									
KYO ST2015									
KYO ST2016									

Table #9

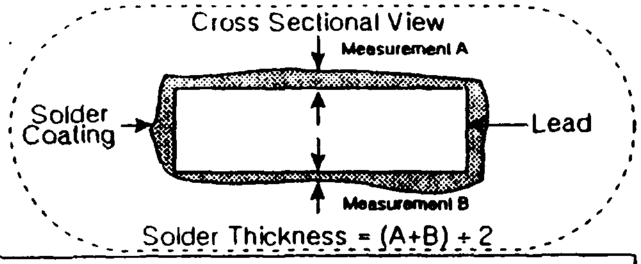
Lead-to-Lead Gap Reduction data collection sheet
(Use one sheet for all devices)

Measurements are to be in mils
(Thousandths of an inch)



Gap Reduction Count and Worst Case Dimension									Worst Case For All 4 Sides
	Side 1		Side 2		Side 3		Side 4		
Serial Number	Count	[illegible]	Count	[illegible]	Count	[illegible]	Count	[illegible]	
KYO ST2001									
KYO ST2002									
KYO ST2003									
KYO ST2004									
KYO ST2005									
KYO ST2006									
KYO ST2007									
KYO ST2008									
KYO ST2009									
KYO ST2010									
KYO ST2011									
KYO ST2012									
KYO ST2013									
KYO ST2014									
KYO ST2015									
KYO ST2016									

Table #10



Solder Thickness data collection sheet

(One sheet for each device)

Device serial number ______________

Side	Lead Numbers (Measure these leads as indicated above)
1	01___ 09___ 17___ 25___ 33___ avg___
2	34___ 42___ 50___ 58___ 66___ avg___
3	67___ 75___ 83___ 91___ 99___ avg___
4	100___ 108___ 116___ 124___ 133___ avg___

Interoffice Correspondence
TRW Avionics & Surveillance Group

91.Q602.PCC.ST3.1

Subject	Date	From
Detailed Experimental Plan Component Standoff (ST31)	11 February 1991	P. CREPEAU
To	**cc**	**Location/Phone**
P. Glaser	D. Cavanaugh P. Finkenbinder J. Murray T. Neillo	RC 4/1073/3182

I. INTRODUCTION

This IOC presents the detailed experimental plans and procedures for performing the Subtask 3, Part 1 experimental procedure. This experiment is designed to identify significant inter-workstation process variables that effect several responses for the Component Stand-Off workcell.

The significant process variables were identified in a 'brain storming' session among several manufacturing and process engineers. Figure 1 presents a cause and effect diagram that identifies the process variables and responses for the Component Stand-Off workcell. The encircled process variables are those being evaluated in this experiment. The unenclosed process variables are intra-station variables that were previously evaluated and reported.

Ranges (or levels) for the process variables were selected based on tolerances that were expected to be encountered on the factory floor. These ranges, the instruments used to measure the variables, and the reference to the source for the ranges are presented in Table 1. Asterisks identify those process variables being evaluated by this experiment. The response to be analyzed for the Component Stand-Off workstation, the instrument used to measure the response, the specification limit for the response, and the source for the specification limits are presented in Table 2. This experimental design is a fractional factorial with seven process variables. One reflection is required to resolve potential interaction effects. One replicate will also be run. Table 3 presents the form that will be used for the response evaluated by this experimental design.

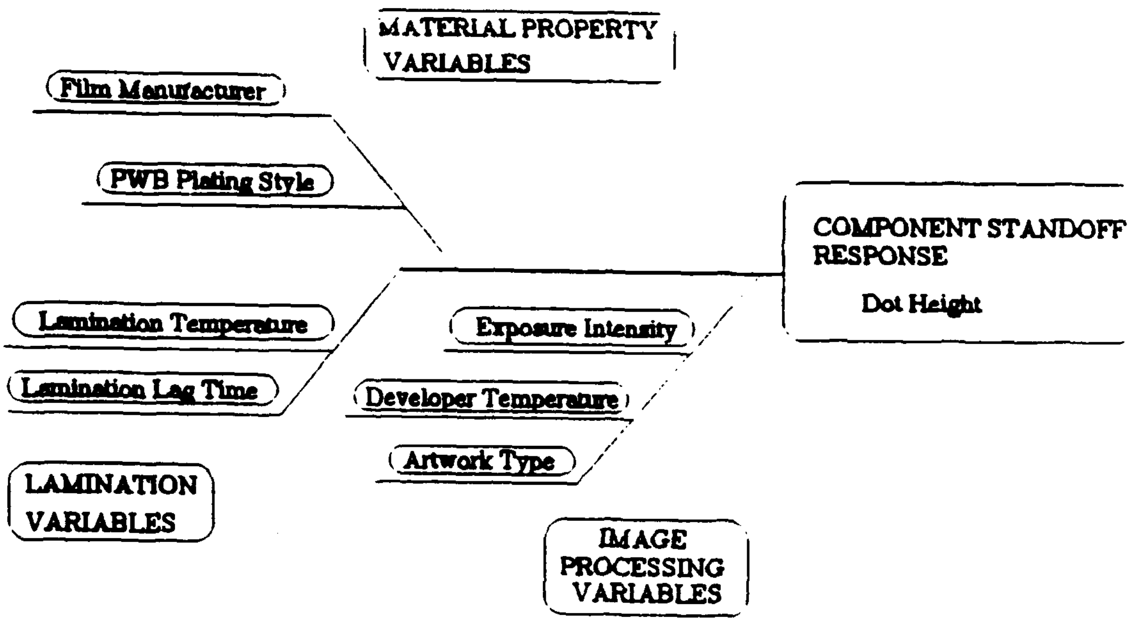


Figure 1
Component Stand-Off
Cause And Effect Diagram

Table 1

Process Variable Details

	Process Variable	Measuring Device/ Precision	Variable Range	Specification
*	Dry film developer temperature	Thermocouple indicato +/- 1 deg F	90 to 105 F	Vendor product data
*	Dry film exposure intensity	Watt meter +/- 10 watts	2500 to 5000 watts	Vendor product data
*	Solder mask vendor	Invoice	DuPont and Dynachem	TRW design options
*	PWB plating style	Invoice	Fused tin-lead and solder dip and hot air leveled	TRW design options
*	Lamination temperature	Thermocouple/ +/- 1 deg C	Nominal +/- 5 deg C	Vendor product data
*	Lamination lag time to processing	Clock/ +/- 10 mins	Nominal plus 24 hours	Vendor product data
*	Style of process film	Visual	diazo and silver halide	General shop practice

* Process variable being studied by this experiment

Table 2

Response Variable Details

Response Variable	Measuring Device/ Precision	Specification Limit	Specification
Stand-off dot height	Surface Gauge/ +/- 0.1 mils	4 to 6 mils	Baseline document

Table 3

Response Table With Interaction Effects

Random Order Trial Number	Standard Order Trial Number	Response Observed Value	A		B		C		AB		AC		BC		ABC	
			1	2	1	2	1	2	1	2	1	2	1	2	1	2
	1															
	2															
	3															
	4															
	5															
	6															
	7															
	8															
TOTAL																
NUMBER OF VALUES																
AVERAGE																
EFFECT																

II. MATERIALS AND SUPPLIES

PWB.-

Qty	PIN	Description
12	786582A	Solder dipped and hot air leveled, no fiducial stretch
	Serial Numbers	A-26, -30, B-60, -65, -67, -75, -78, -82, and four that are tbd
12	786582C	Fused tin-lead, no fiducial stretch
	Serial Numbers	C-106, -131, D-155, -157, -158, -160, -176, -182, and four that are tbd

Artwork.-

PIN	Description
T786582-5/2	0.020-in pad diameter solder mask pattern

Solder Paste.- (None required)

Stencil.- (None required)

Miscellaneous.-

96244 Protective gloves	Jones Associates

Solvents.-

Isopropyl alcohol	TT-I-335
1,1,1-Trichloroethane	MIL-T-81533

III TOOLS AND EQUIPMENT

Dry film laminator

Dry film exposure unit

Dry film developer

Surface gauge

Thermocouple surface temperature indicator

IV PROCEDURE

1. Select four 786582A or -B PWBs and serialize as ST3P1A-26, -30, -B-60, and -65; select four 786582C or -D PWBs and serialize as ST3P1C-106, -131, -D-155, and -157. These will represent the two different styles of PWB solder finishes.

2. Select two different dry film solder masks vendors and one dry film solder mask from each. Log and record the identification.

3. The worksheet shown in Table 7 is to be used to run the first experimental matrix for the 'height' response listed in Table 2. Column A is assigned to the 'Dry Film Vendor'; sub-column 1 is for 'DuPont', sub-column 2 is for 'Dynachem'. Column B is assigned to the 'Exposure Intensity'; sub-column 1 is for '2500 watts'; sub-column 2 is for '5000 watts Column C is assigned to the 'Developer Temperature'; sub-column 1 is for '90 deg F'; sub-column 2 is for the '105 deg F. Column AB is assigned to the 'Lamination Temperature'; sub-column 1 is for 'Nominal Minus 5 Deg C'; sub-column 2 is for 'Nominal Plus 5 Deg C'. Column AC is assigned to the 'Lamination Lag Time'; sub-column 1 is for 'Zero Lag Time'. sub-column 2 is for a '24 Hour Lag Time'. Column BC is assigned to the 'PWB Plating Style'; sub-column 1 is for 'Fused Tin-Lead'; sub-column 2 is for 'Solder Dipped and Hot Air Leveled'. Column ABC is assigned to the 'Process Film Style; sub-column 1 is for 'Diazo film'; sub-column 2 is for 'Silver halide film'.

4. Use the randomized run numbers in the "Random Order Trial Number" column. Sequence the experiment trials using this random number sequence.

5. Clean the serialized PWBs in accordance with the applicators recommendations.

6. Laminate, store, expose, and develop the dry-film solder mask onto the PWB for all the appropriate conditions indicated for the particular experiment being run. Use this processed PWB to collect data for the single response listed in Table 2. Repeat until all eight experiments have been run.

7. The sub-column 1 and 2 range assignments for each process variable column in the Table 7 test matrix were inverted to create the Table 8 worksheet. The run order was rerandomized. Using this new experimental matrix, rerun the experiment. This will result in a reflected set of data to aid in the isolation of interaction effects between the process variables assigned to columns AB, AC, BC, and ABC.

7.a. The serial numbers of these PWBs are: ST3P1B67, -75, -78, -82, and -75 for the solder dipped and hot air leveled PWB styles; and ST3P1D158, -160, -176, and -182 for the fused tin-lead styles.

V. RESPONSE DATA

A. Solder Mask Dot Height, 20-Pin LCC Pattern, Adjacent to Pattern

1. Using a surface gauge, measure the developed solder mask dot heights adjacent to footprint patterns at the locations listed in Table 4.

B. Solder Mask Dot Height, 20-Pin LCC Pattern, 50 Mils from Pattern

1. Using a surface gauge, measure the developed solder mask dot heights 50 mils from adjacent footprint patterns at the locations listed in Table 4.

C. Solder Mask Dot Height, 28-Pin LCC Pattern, Adjacent to Pattern

1. Using a surface gauge, measure the developed solder mask dot heights adjacent to footprint patterns at the locations listed in Table 5.

D. Solder Mask Dot Height, 28-Pin LCC Pattern, 50 Mils from Pattern

1. Using a surface gauge, measure the developed solder mask dot heights 50 mils from adjacent footprint patterns at the locations listed in Table 5.

E. Solder Mask Dot Height, 32-Pin LCC Pattern, Adjacent to Pattern

1. Using a surface gauge, measure the developed solder mask dot heights adjacent to footprint patterns at the locations listed in Table 6.

F. Solder Mask Dot Height, 32-Pin LCC Pattern, 50 Mils from Pattern

1. Using a surface gauge, measure the developed solder mask dot heights 50 mils from adjacent footprint patterns at the locations listed in Table 6.

Note.- The 132-pin FPD is kept off of the PWB surface by its lead form and does not require solder mask standoffs. Also, solder mask standoffs are not required under chip components.

VI. DATA REDUCTION

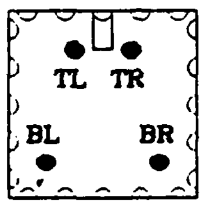
1. Using the data gathered by this experiment, the response sheets typified by Table 3 will be completed for the responses; and significant interstation process variables will be identified.

2. Additional analyses of the data using analysis of variance (ANOVA) techniques will yield variability, experimental error, and process capability indices data.

3. The analysis and comparison of the reflected matrix with the straight matrices will enable process variable interaction effects to be isolated for those variables assigned to columns AB, AC, BC, and ABC.

Table 4

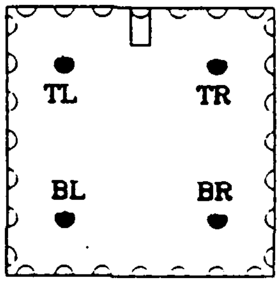
Standoff Heights
20-Pin LCCs



Component	Standoff Height, mils			
	separated		adjacent	
	TL	TR	BL	BR
U02				
U05				
U19				
U28				
U33				

Table 5

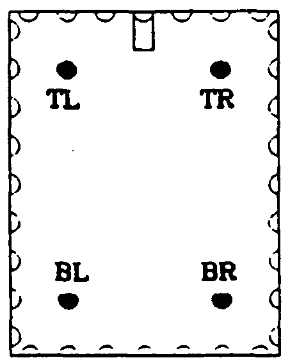
Standoff Heights
28-Pin LCCs



Component	Standoff Height, mils			
	separated		adjacent	
	TL	TR	BL	BR
U22				
U26				
U31				
U35				
U37				

Table 6

Standoff Heights
32-Pin RLCCs



Component	Standoff Height, mils			
	separated		adjacent	
	TL	TR	BL	BR
U22				
U26				
U31				
U35				
U37				

Table 7

'Normal' Experimental Run Matrix'

Random Order Trial Number	Standard Order Trial Number	PWB Serial Number	A		B		C		AB		AC		BC		ABC		RESPONSE
			Dry Film Vendor		Exposure Intensity watts		Developer Temperature deg F		Dry Film Lam. Temp. C from nom		Dry Film Proc Lag Time hours		PWB Style		Process Film Style diazo/halide		
			1	2	1	2	1	2	1	2	1	2	1	2	1	2	
4	1	A-26	DuP		2500		90			+5		24		air	diazo		
5	2	C-106	DuP		2500			105		+5	0		fused			halide	
8	3	C-131	DuP			5000	90		-5			24	fused			halide	
3	4	A-30	DuP			5000		105	-5		0			air	diazo		
1	5	B-60		Dyn	2500		90		-5		0			air		halide	
6	6	D-155		Dyn	2500			105	-5			24	fused		diazo		
7	7	D-157		Dyn		5000	90			+5	0		fused		diazo		
2	8	B-65		Dyn		5000		105		+5		24		air		halide	

Table 8

'Reflected' Experimental Run Matrix

Random Order Trial Number	Standard Order Trial Number	PWB Serial Number	A Dry Film Vendor		B Exposure Intensity watts		C Developer Temperature deg F		AB Dry Film Lam. Temp. C from nom		AC Dry Film Proc Lag Time hours		BC PWB Style		ABC Process Film Style diazo/halide		RESPONSE
			1	2	1	2	1	2	1	2	1	2	1	2	1	2	
6	1	D-158		Dyn		5000		105	-5		0		fused			halide	
4	2	B-67		Dyn		5000	90		-5			24		air	diazo		
8	3	B-75		Dyn	2500			105		+5	0			air	diazo		
2	4	D-160		Dyn	2500		90			+5		24	fused			halide	
1	5	D-176	DuP			5000		105		+5		24	fused		diazo		
5	6	B-78	DuP			5000	90			+5	0			air		halide	
7	7	B-82	DuP		2500			105	-5			24		air		halide	
3	8	D-182	DuP		2500		90		-5		0		fused		diazo		

Interoffice Correspondence
TRW Avionics & Surveillance Group

91.Q602.PCC.ST3.2

Subject	Date	From
Detailed Experimental Plan PWA Cleaning (ST32)	26 January 1991	P. CREPEAU
To	**cc**	**Location/Phone**
P. Glaser	D. Cavanaugh P. Finkenbinder J. Murray T. Neillo	RC4/1073/3182

I. INTRODUCTION

This IOC presents the detailed experimental plans and procedures for performing the Subtask 3. Part 2 experimental procedure. This experiment is designed to identify significant inter-workstation process variables that effect several responses for the PWA Cleaning workcell.

The significant process variables were identified in a 'brain storming' session among several manufacturing and process engineers. Figure 1 presents a cause and effect diagram that identifies the process variables and responses for the PWA Cleaning workcell. The shaded process variables are those being evaluated in this experiment. The unshaded process variables are intra-station variables that were previously evaluated and reported.

Ranges (or levels) for the process variables were selected based on tolerances that were expected to be encountered on the factory floor. These ranges. the instruments used to measure the variables. and the reference to the source for the ranges are presented in Table 1. Double asterisks identify those process variables being evaluated by this experiment. Responses to be analyzed for the PWA Cleaning workstation. the instruments used to measure the responses. the specification limits for the responses. and the source for the specification limits are presented in Table 2. This experimental design is a fractional factorial with five process variables. Columns BC and ABC will be used for experimental error measurements. One reflection is required to resolve potential interaction effects. One replicate will also be run. Table 3 presents the form that will be used for each response evaluated by this experimental design.

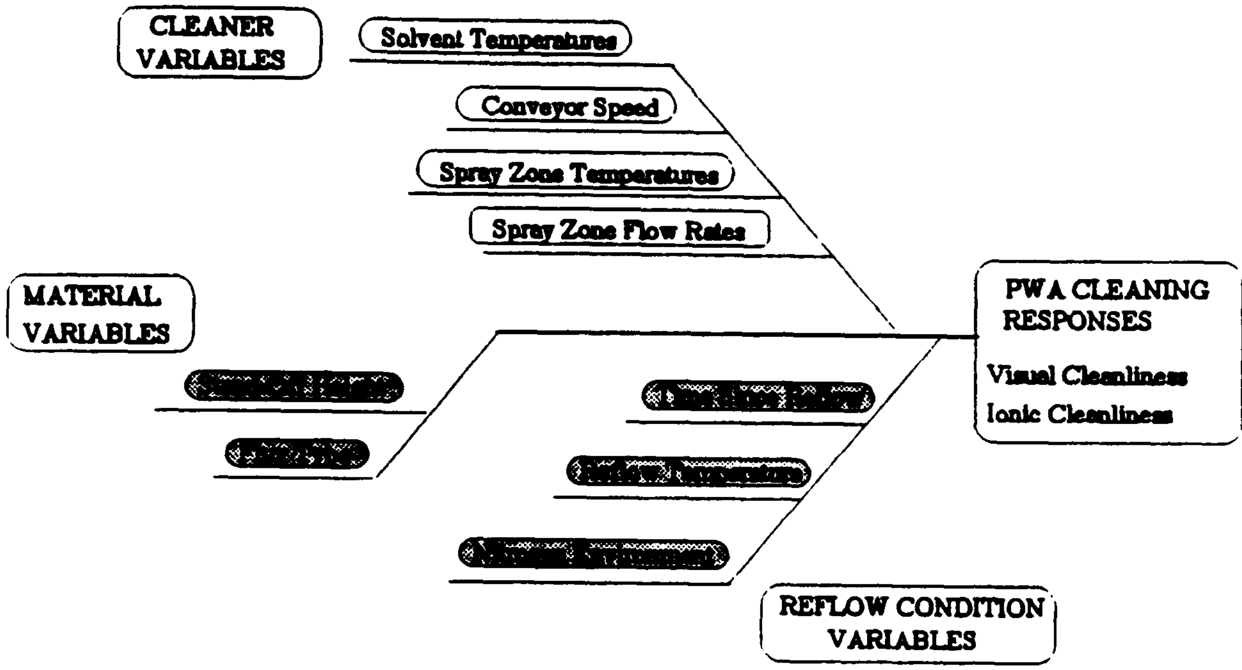


Figure 1

Component Stand-Off
Cause And Effect Diagram

Table 1

Process Variable Details

	Process Variable	Measuring Device/ Precision	Variable Range	Specification
*	Time since reflow	Timer/ +/- 1 min	0 to 30 mins	Baseline document
*	Reflow temperature	Thermocouple/ +/- 1 deg C	210 to 220 deg C	Baseline document
*	Nitrogen environment	Oxygen analyzer/ +/- 2 percent	70 to 98 percent	Baseline document
*	Component stand-off height	Surface gauge/ +/- 0.1-mils	4 to 6 mils	Baseline document
*	Solder paste vendor	not applicable	Metech and Multicore	TRW solder paste evaluation
	Solvent temperature	Thermocouple/ +/- 1 deg C	140 to 160 deg F	Baseline document
	Conveyor speed	Common operator interface/+/- 0.1 fpm	1 to 3 fpm	Baseline document
	Spray zone temperatures	Common operator interface/+/- 1 psi	40 to 50 psi and 170 to 190 psi **	Baseline document

* Process variable being studied by this experiment

** 40 to 50 psi applies to nominal spray pressures of 45 psi; 170 to 190 psi applies to nominal spray pressures of 180 psi.

Table 2

Response Variable Details

Response Variable	Measuring Device/ Precision	Specification Limit	Specification
Visual cleanliness	Comparison to visual standards/ +/- 1 unit	1 to 5 units	MIL-P-28809
Ionic cleanliness	Ionic contamination tester/+/- 1 ugm NaCl/sq in	0 to 10 ugm NaCl/sq in	MIL-C-28809

Table 3

Response Table With Interaction Effects

Random Order Trial Number	Standard Order Trial Number	Response Observed Values	A		B		C		AB		AC		BC		ABC	
			1	2	1	2	1	2	1	2	1	2	1	2	1	2
	1															
	2															
	3															
	4															
	5															
	6															
	7															
	8															
TOTAL																
NUMBER OF VALUES																
AVERAGE																
EFFECT																

II. MATERIALS AND SUPPLIES

PWB.-

Qty	PIN	Description
24	786582A	Solder dipped and hot air leveled. no fiducial stretch

Components.-

Qty	PIN	Description
72		132-pin. NTK. FPD package
432		20-pin. LCC
240		28-pin. LCC
192		32-pin. RLCC
912		M55342/6. chip resistor
1008		CDR02. chip capacitor
144		CWR06. chip capacitor

Solder Paste.-

Metech RHF63	Metech. Inc Route 401 Halverson. PA 19520
Multicore SN62RM92A90	Multicore Solders Cantiague Rock Road Westbury. NY 11590

Stencil.-

T786582-6/1 T786582-6/2	6/12 thickness

Dry Film Solder Mask.-

DuPont xx yy	E.I. DuPont de Nemours Wilmington. DE

Dynachem xx yy	Dynachem. Corp 2631 Michelle Dr Tustin. CA 92680

Solder Mask Artwork.-

T786582-5/1
T786582-5/2

Miscellaneous.-

Palette knife. plastic Holbein	
Bristle brush	
Shamis 99-150 cleaning cloth	Affiliated Manufacturers. Inc.
96244 Protective gloves	Jones Associates

Solvents.-

Isopropyl alcohol	TT-I-335
1.1.1-Trichloroethane	MIL-T-81533

III TOOLS AND EQUIPMENT

General purpose stereoscope. 0.7X to 3X zoom with an American Optical No. 424. 10X. filar eyepiece

Screen Printer No. 24-ASP	MPM Corporation 10 Forge Park Franklin. MA 02038
Malcom Viscometer	Austin American Technology 12201 Technology Blvd. Austin. TX 78727
Gelzer Robot	Gelzer Systems Westerville. OH
In-Line Cleaner. CBL-18	Baron Blakeslee 2001 N. Janice Ave. Melrose Park. IL 60160
Stencil Cleaner	Tooltronics. Inc. 710 Ivy St.

	Glendale, CA 91204
Microscan	CyberOptics Corp. 2331 University Ave. S.E. Minneapolis, MN 55414
IR Reflow Oven, Model SMD 722	Vitronics Corp 40 Forge Haymarket, NH
Ionic Contamination Tester Model ICOM 4000	Westek, Inc. 400 Rolyn Place Arcadia, CA 91006

IV PROCEDURE

1. Select 24 786582A PWBs and serialize as ST3P2001 through -024, and set aside in groups of eight for the three experiments being run.

2. Create one worksheet similar to the one shown in Table 3, for each of the responses listed in Table 2, that are to be monitored. Column A is assigned to the 'Nitrogen Environment'; sub-column 1 is for 79 percent nitrogen; sub-column 2 is for 98 percent nitrogen. Column B is assigned to the 'Reflow Temperature'; sub-column 1 is for '210 deg ; sub-column 2 is for '220 deg C'. Column C is assigned to the 'Time Since Reflow'; sub-column 1 is for 'zero time'; sub-column 2 is for the 'zero time plus 30 minutes'. Column AB is assigned to the 'Solder Paste Vendor'; sub-column 1 is for 'Metech'; sub-column 2 is for 'Multicore'. Column AC is assigned to the 'Standoff Height'; sub-column 1 is for 'four mils standoff'; sub-column 2 is for 'six mils standoff'. Columns BC and ABC are reserved for experimental error determinations.

3. Randomize the "Standard Order Trial Number" column, and enter the appropriate random number in the "Random Order Trial Number" column. Run the experiment trials using the random number sequence.

4. Completely process the PWBs using all of the nominal processing variables used in these subtask studies. The exceptions, of course, are those process variables being investigated for this specific subtask.

5. Invert the sub-column 1 and two range assignments for each process variable column in the test matrix. Rerandomize the run order numbers and, rerun the experimental matrix. This will result in a reflected set of data to aid in the isolation of interactive effects between the process variables assigned to columns AB, AC, BC, and ABC.

V RESPONSE DATA

A. Visual Cleanliness

1. Scan the entire PWA and compare and rank the cleanliness against the visual standards presented in Figure 2.

B. Ionic Contamination

1. Measure the cleanliness of the PWA using the Westek ICOM 4000.

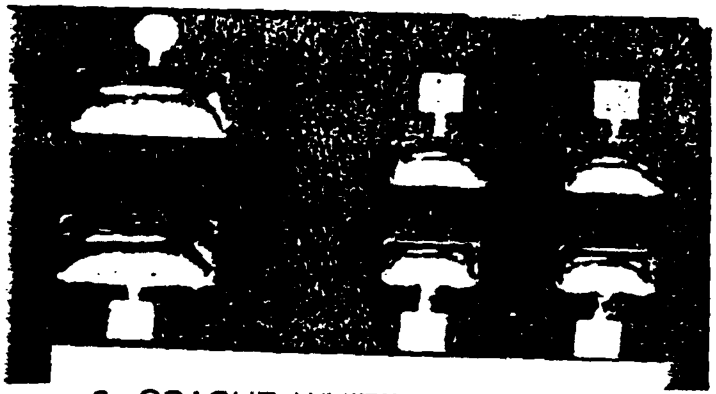
Figure 2

Visual PWA Cleanliness Standards

0 NO CONTAMINATION VISIBLE REGARDLESS OF LIGHT OR MAGNIFICATION (MAX 30X)

1 EDGE OF VISIBILITY, TRANSPARENT DRY RESIDUE

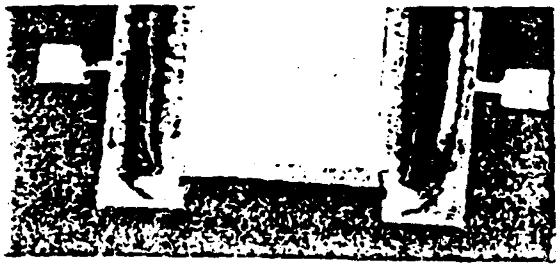
2 EASILY VISIBLE, TRANSPARENT DRY RESIDUE



3 OPAQUE, WHITE DRY DEPOSIT

4 LIGHT DEPOSIT OF WET FLUX

5 HEAVY DEPOSIT OF WET FLUX



VI. DATA REDUCTION

1. Using the data gathered by this experiment, the response sheets typified by Table 3 will be completed for the responses; and significant interstation process variables will be identified.

2. Additional analyses of the data using analysis of variance (ANOVA) techniques will yield variability, experimental error, and process capability indices data.

3. The analysis and comparison of the reflected matrix with the straight matrices will enable process variable interaction effects to be isolated for those variables assigned to columns AB and AC.

Interoffice Correspondence
TRW Avionics & Surveillance Group

91.Q602.PCC.ST4.0

Subject	Date	From
Detailed Experimental Plan Fine Pitch Device Forming (ST40)	12 February 1991	T. NEILLO
To	**cc**	**Location/Phone**
P. Glaser	D. Cavanaugh P. Finkenbinder J. Murray P. Crepeau	RC4/1073/3605

SUBTASK 4

FINE PITCH DEVICE LEAD FORMING

I. INTRODUCTION

This document presents the detailed experimental plan and procedures for performing the Sub Task 4 experimental procedure. This experiment is designed to identify significant inter-workstation process variables that effect several responses for the fine pitch device lead forming (FPD) work cell. The significant process variables were identified in a "brainstorming" session among several manufacturing and process engineers. Figure 1 presents a cause and effect diagram that identifies the process variables and responses for the FPD lead forming work cell. The shaded process variables are those being evaluated in this experiment. The unshaded process variables are intrastation variables that were previously evaluated and reported.

Ranges (or levels) for the process variables were selected based on tolerances that were expected to be encountered on the factory floor. These ranges, the instruments used to measure the variables, and the reference to the source for the ranges are presented in Table 1. Double asterisks identify those process variables being evaluated by this experiment. Responses to be analyzed for the FPD lead forming workstation, the instruments used to measure the responses, the specification limits for the responses, and the source for the specification limits are presented in Table 2. This experimental design is a full factorial with three variables. No reflection is required. One replicate will be run, however.

Table 3 presents the form that will be used for each response evaluated by this experimental design. Columns AB, AC, BC, and ABC will be used for experimental error measurements.

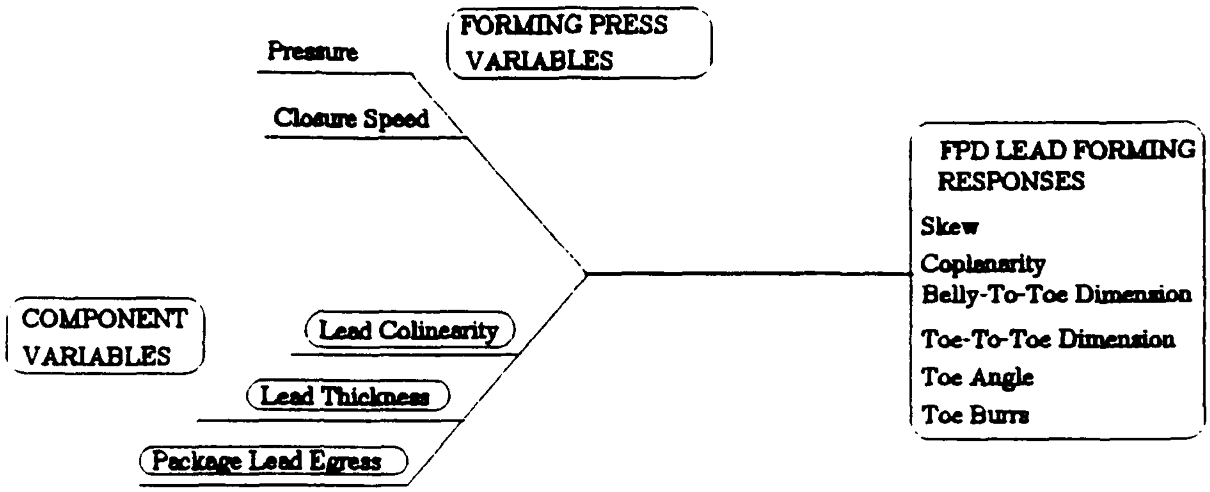


Figure 1. FPD component forming fishbone chart.

Table 1. Process variable details.

Process Variable	Measuring Device/ Precision	Variable Range	Specification
Die pressure	Pressure gauge/ +/- 1 psi	80-90 psi 85 psi nominal	TRW EOP
Die closure rate	Stop watch/ +/- 0.1 sec	0.055-0.057 ft/s 0.056 ft/s nom.	TRW EOP
**Lead colinearity	Microscope with filar/ +/- 0.1-mil	+/- 3 mils from orthogonal	Engineering
**Lead thickness	Micrometer/ +/- 0.1-mil	5 to 8 mils	Vendor drawing requirements
**Lead package egress	Microscan/ +/- 0.1-mil	From top of package or side of package	Vendor drawing requirements

Table 2. Response variable details.

Response Variable	Measuring Device/ Precision	Specification Limit	Specification
Skew	Microscope with filar/ +/- 0.1-mil	-2 to +2 mils from orthogonal	MIL-STD-2000
Coplanarity	Microscan/ +/- 0.1-mil	4 mil maximum deviance	Engineering
"Belly-to-toe" dimension	Microscan/ +/- 0.1 mil	10 mils +/- 2 mils	TRW drawing
"Toe-to-toe" dimension	Coordinatograph/ +/- 0.1-mil	Nominal/ +/- 5 mils	TRW drawing
"Toe" angle dimension	Microscan/ +/- 0.1-mil	+/- 15 deg from horizontal	MIL-STD-2000
"Toe" burrs	Microscope with filar/ +/- 0.1 mil	1x lead thickness, max.	MIL-STD-2000

Table 3. Response table with interaction effects.

Random Order Trial Number	Standard Order Trial Number	Response Observed Values	A		B		C		AB		AC		BC		ABC	
			1	2	1	2	1	2	1	2	1	2	1	2	1	2
	1															
	2															
	3															
	4															
	5															
	6															
	7															
	8															
TOTAL																
NUMBER OF VALUES																
AVERAGE																
EFFECT																

Serial number/Process Variable Relationship Matrix

	Package Style		Lead Thickness		Lead Skew		Run Number	
Serial Number	Diacon	Kyocera	5 mils	8 mils	-3 mils	+3 mils	Initial	Replicat.
DIA ST4001	XX			XX	XX		3	
DIA ST4002	XX			XX	XX			3
DIA ST4003	XX			XX		XX	4	
DIA ST4004	XX			XX		XX		4
DIA ST4005	XX		XX		XX		1	
DIA ST4006	XX		XX		XX			1
DIA ST4007	XX		XX			XX	2	
DIA ST4008	XX		XX			XX		2
KYO ST4001		XX		XX	XX		7	
KYO ST4002		XX		XX	XX			7
KYO ST4003		XX		XX		XX	8	
KYO ST4004		XX		XX		XX		8
KYO ST4005		XX	XX		XX		5	
KYO ST4006		XX	XX		XX			5
KYO ST4007		XX	XX			XX	6	
KYO ST4008		XX	XX			XX		6

Figure 2

Robotic Workcell, [response name] experimental design matrix

Initial Run

Random Sequence Number	Run Number	Proposed/Actual Variable States: Package Style Prop.	Package Style Act.	Lead Thickness Prop.	Lead Thickness Act.	Lead Skew Prop.	Lead Skew Act.		
4	DIA 1 ST4005	DIA		5 mils		-3 mil		EXPERIMENTAL ERROR	
6	DIA 2 ST4007	DIA		5 mils		+3 mil			
1	DIA 3 ST4001	DIA		8 mils		-3 mil			
2	DIA 4 ST4003	DIA		8 mils		+3 mil			
5	KYOC 5 ST4005	KYOC		5 mils		3 mil			
7	KYOC 6 ST4007	KYOC		5 mils		+3 mil			
3	KYOC 7 ST4001	KYOC		8 mils		3 mil			
8	KYOC 8 ST4003	KYOC		8 mils		+3 mil			

Figure 3

Robotic Workcell, [response name] experimental design matrix

Replication

Random Sequence Number	Run Number	Proposed/Actual Variable States							
		Package Style		Lead Thickness		Lead Skew			
		Prop.	Act.	Prop.	Act.	Prop.	Act.		
3	DIA 1 ST4006	DIA		5 mils		3 mil		EXPERIMENTAL ERROR	
8	DIA 2 ST4008	DIA		5 mils		+3 mil			
4	DIA 3 ST4002	DIA		8 mils		-3 mil			
7	DIA 4 ST4004	DIA		8 mils		+3 mil			
6	KYOC 5 ST4006	KYOC		5 mils		3 mil			
2	KYOC 6 ST4008	KYOC		5 mils		+3 mil			
5	KYOC 7 ST4002	KYOC		8 mils		3 mil			
1	KYOC 8 ST4004	KYOC		8 mils		+3 mil			

Figure 4

II. MATERIALS AND SUPPLIES

PWB - (None required)

Components

Qty	P/N	Description
8	132-pin FPD	Kyocera
8	132-pin FPD	Diacon

Solder paste - (None required)

Stencil - (None required)

Miscellaneous - (None required)

Solvents - (None required)

III. EQUIPMENT, TOOLS AND SUPPORTING DOCUMENTATION

Gelzer integrated preparation and placement workstation (Model #1312).

EOP 10160 (Equipment Operating Procedure for the Gelzer Preparation and Placement Workstation)

General purpose stereo microscope, 0.7x-3x zoom with an American Optical No. 424, 10x filar eyepiece.

Microscan	CyberOptics Corp. 2331 University Ave SE Minneapolis, MN 55414
Dial Micrometer	Lukins or equivalent
Coplanarity measurement aids	TL001-FORM-1 TL001-FORM-2

IV. PROCEDURE

A.

NOTE: **Refer to the "SERIAL NUMBER/PROCESS VARIABLE RELATIONSHIP MATRIX" (see figure #2) when serializing the FPD packages to determine which variables are forced for each serial number.**

1. Procure eight each of the lidded Kyocera and Diacon 132-pin FPD packages and place a black ink dot on the lid of all 16 packages to indicate pin #1 (see figure #5). Use the same convention for each part type!

2. Select four Kyocera and four Diacon 132-pin FPD packages, measure their lead thickness, and have them copper, nickel, and gold plated to an additional 3 mils of thickness. Serialize them as KYO ST4001 through -004 and DIA ST4001 through -004.

3. Select four Kyocera and four Diacon 132-pin packages. Measure their lead thickness. Serialize them as KYO ST4005 through -008 and DIA ST4005 through -008.

4. Locate the following FPD serial numbers and skew the indicated leads -3 mils. from the orthogonal, at a point located 0.180" from the package body (see figure 7):

<u>FPD SERIAL NUMBER</u>

DIA ST4001	KYO ST4001
DIA ST4002	KYO ST4002
DIA ST4005	KYO ST4005
DIA ST4006	KYO ST4006

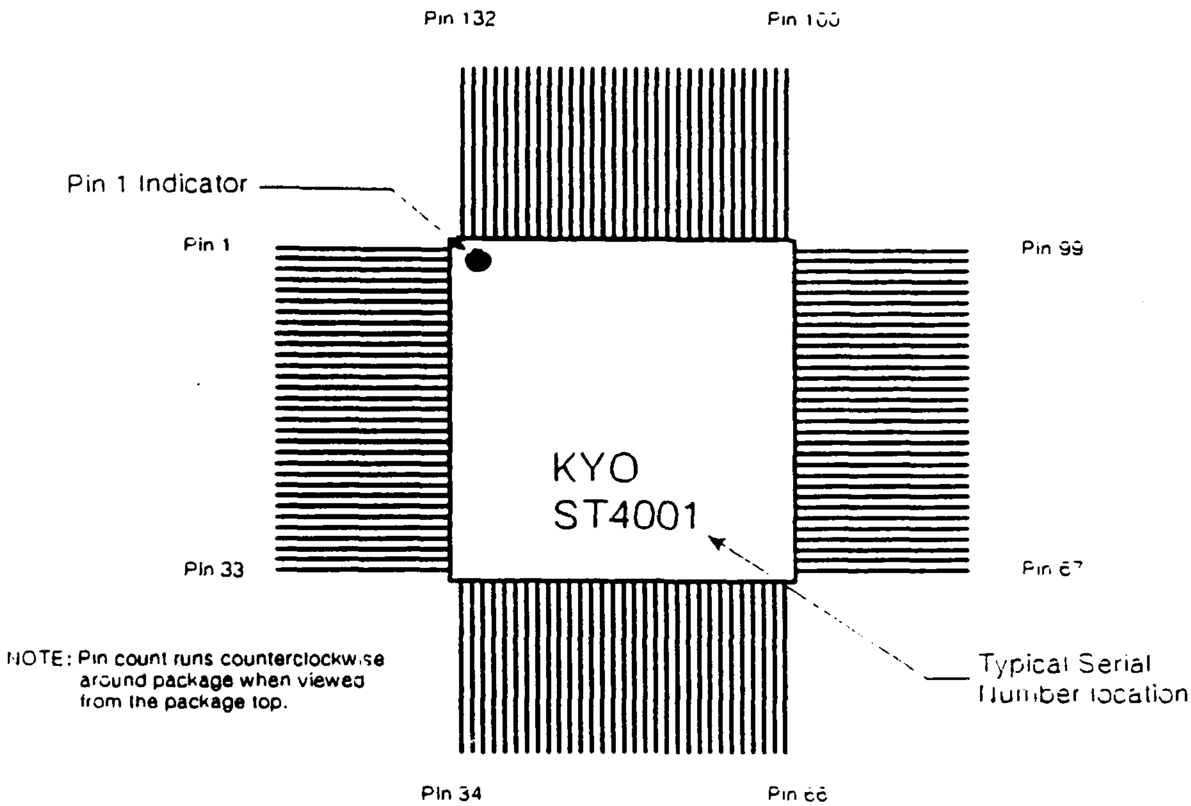
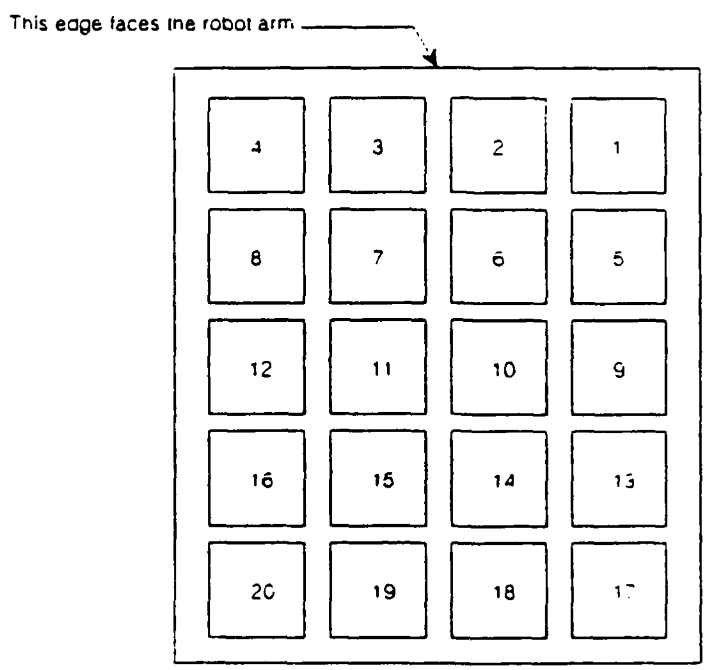


FIGURE #5



Preparation side elevator feeder tray #1 pocket locations and numbering scheme.

FIGURE #6

<u>**SKEWED LEAD NUMBERS**</u>

SIDE 1: 1, 2, 3, 16, 17, 18, 31, 32 and 33

SIDE 2: 34, 35, 36, 49, 50, 51, 64, 65 and 66

SIDE 3: 67, 68, 69, 82, 83, 84, 97, 98 and 99

SIDE 4: 100, 101, 102, 115, 116, 117, 130, 131 and 132

5. Locate the following FPD serial numbers and skew the indicated leads +3 mils, from the orthogonal, at a point located 0.180" from the package body (see figure 7):

<u>**FPD SERIAL NUMBER**</u>

DIA ST4003	KYO ST4003
DIA ST4004	KYO ST4004
DIA ST4007	KYO ST4007
DIA ST4008	KYO ST4008

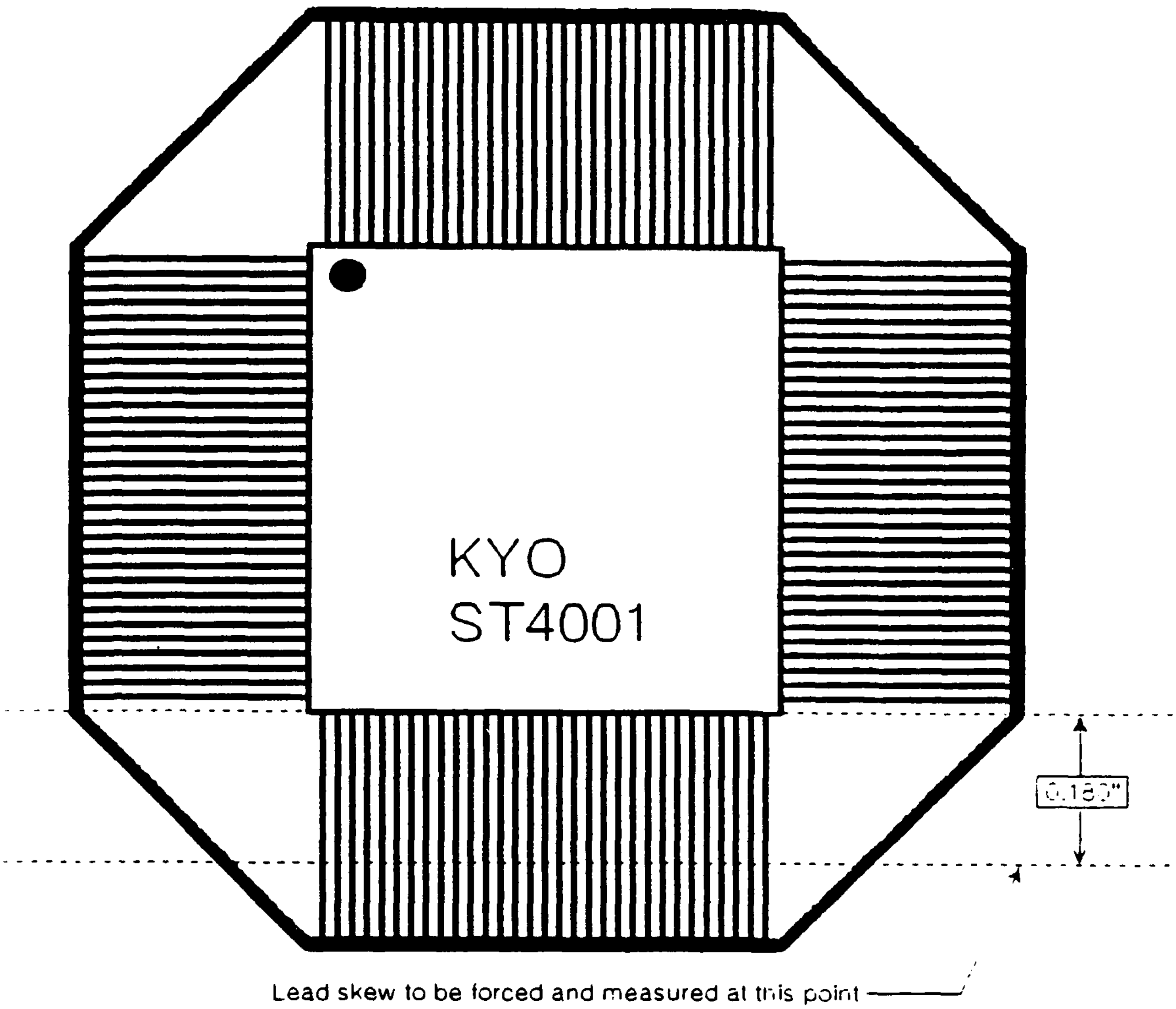
<u>**SKEWED LEAD NUMBERS**</u>

SIDE 1: 1, 2, 3, 16, 17, 18, 31, 32 and 33

SIDE 2: 34, 35, 36, 49, 50, 51, 64, 65 and 66

SIDE 3: 67, 68, 69, 82, 83, 84, 97, 98 and 99

SIDE 4: 100, 101, 102, 115, 116, 117, 130, 131 and 132



Lead skew shall be forced and measured at a point on each lead that lies 0.180" from the package bdy (see above example). This point on the lead represents the toe of the lead after forming has been performed and shall be typical of all four sides.

FIGURE #7

6. Measure the coplanarity, before forming, for each of the devices and record this "original condition" data in table 5. Use the Microscan and TL001-FORM-1 to accomplish this.

NOTE: Use one sheet for each device!

7. Create one worksheet each, similar to the one shown in Table 3, for the initial run and for the replication (see figures #3 & #4). Column A is assigned to the 'Lead Package Egress Style', subcolumn 1 is for 'Diacon', subcolumn 2 is for 'Kyocera'. Column B is assigned to 'Lead Thickness', subcolumn 1 is for 'Nominal', subcolumn 2 is for 'Plus 3 Mils'. Column C is assigned to 'Lead Skew', subcolumn 1 is for a skew of '-3 Mils', subcolumn 2 is for a skew of '+3 Mils'. The remaining columns are for experimental error determinations.

8. Randomize the "Standard Order Trial Number" column and enter the appropriate random number in the "Random Order Trial Number" column. Run the experiment trials using the random number sequence.

9. Set up the component preparation side of the Gelzer robot minus the lead tinning function and load the forming program "FORM.BBF".

10. Place the appropriate 132-pin packages into the preparation elevator tray #1 in accordance with the **random sequence order number** and starting with pocket #1 (see figure #6). With the feeder tray oriented as shown in figure 6, place the pin #1 indicator of each FPD in the upper left hand corner of the feeder pockets. Form and trim their leads. Collect data for the six responses listed in Table 2. Repeat until all eight experiments have been run.

11. Take some preliminary measurements to confirm that no other significant variables are affecting the process. Stop and notify the cognizant engineer if there appears to be any undocumented outside influences in the process.

12. Rerandomize the run order numbers and rerun the experimental matrix. This will result in a replicate set of data to aid in statistical analyses of the experiment.

V. RESPONSE DATA

A. Lead Skew

1. Measure and record the lead skew or colinearity of the FPD package leads for each of the eight runs at the locations listed in Table 4. Use a coordinatograph to accomplish this. The precision of the measurement shall be 0.1-mil, min.

B. Lead Coplanarity

1. Measure and record the lead coplanarity of the FPD package leads for each of the eight runs at the locations listed in Table 5. Use the Microscan with a precision of 0.1-mil and tool number TL001-FORM-2 to accomplish this.

C. "Belly-to-Toe" Dimensions

1. Measure and record the dimension from the bottom of the FPD ceramic package to the bottom of the "toe" formed on the lead for each of the eight runs at the locations listed in Table 6. Use a Microscan with a precision of 0.1-mil, max.

D. "Toe-to-Toe Dimension

1. Measure and record the minimum and maximum "toe-to-toe" dimension across both sides of the package for each of the eight runs at the locations listed in Table 7. Use a coordinatograph with a precision of 0.1-mil, max.

E. "Toe" Angle

1. Measure and record the angle of "toe" in the formed lead of the FPD for each of the eight runs at the locations listed in Table 8. Use a Microscan with a precision of 0.1-mil, max. and arrive at the angle through triangulation.

F. "Toe" Burrs

1. Scan all of the "toes" of the formed leads of the FPD and select the lead with the greatest burr for each of the four sides. Use a filar eyepiece on a microscope with a precision of 0.1-mil to measure that burr and record its lead number and dimension. See Table 9.

VI. DATA REDUCTION

Using the data gathered by this experiment, the response sheets typified by Table 3 will be completed for each response; and significant interstation process variables will be identified.

Additional statistical analyses of the data using analysis of variance (ANOVA) techniques will yield variability, experimental error, and process capability indices data.

Table #4

Lead Skew data collection sheet (One sheet for each device)

Device serial number ____________________

Side	Lead Numbers (Measure these leads at the lead toe)
1	01___ 02___ 03___ avg___ 16___ 17___ 18___ avg___ 31___ 32___ 33___
2	34___ 35___ 36___ avg___ 49___ 50___ 51___ avg___ 64___ 65___ 66___
3	67___ 68___ 69___ avg___ 82___ 83___ 84___ avg___ 97___ 98___ 99___
4	100___ 101___ 102___ avg___ 115___ 116___ 117___ avg___ 130___ 131___ 132___

Table #5

Lead Coplanarity data collection sheet (One sheet for each device)

Device Serial Number ______________________

	Original Condition			Formed Condition		
Side	Lowest	Highest	Delta	Lowest	Highest	Delta
1						
2						
3						
4						

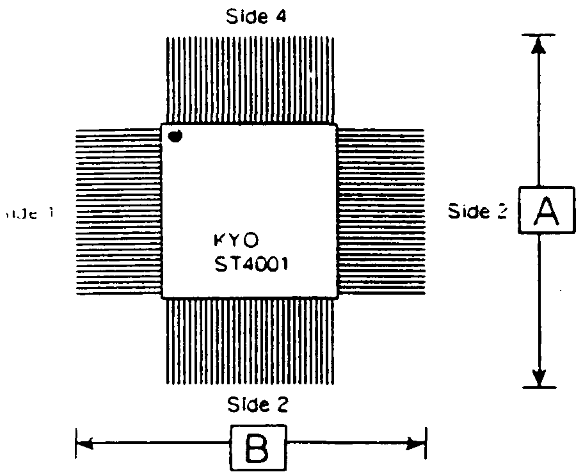
Table #6

Belly-to-Toe data collection sheet (One sheet for each device)

Device serial number ____________________

Side	Lead Numbers (Measure these leads at the lead toe)
1	01___ 02___ 03___ avg___ 16___ 17___ 18___ avg___ 31___ 32___ 33___
2	34___ 35___ 36___ avg___ 49___ 50___ 51___ avg___ 64___ 65___ 66___
3	67___ 68___ 69___ avg___ 82___ 83___ 84___ avg___ 97___ 98___ 99___
4	100___ 101___ 102___ avg___ 115___ 116___ 117___ avg___ 130___ 131___ 132___

Table #7



Toe-to-Toe data collection sheet
(Use one sheet for all devices)

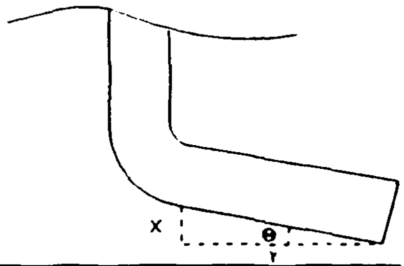
	Dimension A			Dimension B		
Serial Number	Min.	Max.	Avg.	Min.	Max.	Avg.
DIA ST4001						
DIA ST4002						
DIA ST4003						
DIA ST4004						
DIA ST4005						
DIA ST4006						
DIA ST4007						
DIA ST4008						
KYO ST4001						
KYO ST4002						
KYO ST4003						
KYO ST4004						
KYO ST4005						
KYO ST4006						
KYO ST4007						
KYO ST4008						

Table #8

Toe Angle data collection sheet (One sheet for each device)

Device serial number ____________________

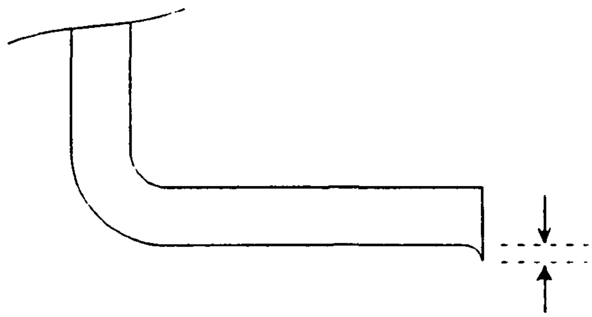
$\Theta = \tan^{-1}\frac{X}{Y}$



Side	Lead Numbers (Measure these leads as shown above)
1	01___ 02___ 03___ avg___ 16___ 17___ 18___ avg___ 31___ 32___ 33___
2	34___ 35___ 36___ avg___ 49___ 50___ 51___ avg___ 64___ 65___ 66___
3	67___ 68___ 69___ avg___ 82___ 83___ 84___ avg___ 97___ 98___ 99___
4	100___ 101___ 102___ avg___ 115___ 116___ 117___ avg___ 130___ 131___ 132___

Table #9

Toe Burr data collection sheet (Use one sheet for all devices)



	Maximum Burr Dimension				Max Dim of
Serial Number	Side 1	Side 2	Side 3	Side 4	All Four Sides
DIA ST4001					
DIA ST4002					
DIA ST4003					
DIA ST4004					
DIA ST4005					
DIA ST4006					
DIA ST4007					
DIA ST4008					
KYO ST4001					
KYO ST4002					
KYO ST4003					
KYO ST4004					
KYO ST4005					
KYO ST4006					
KYO ST4007					
KYO ST4008					

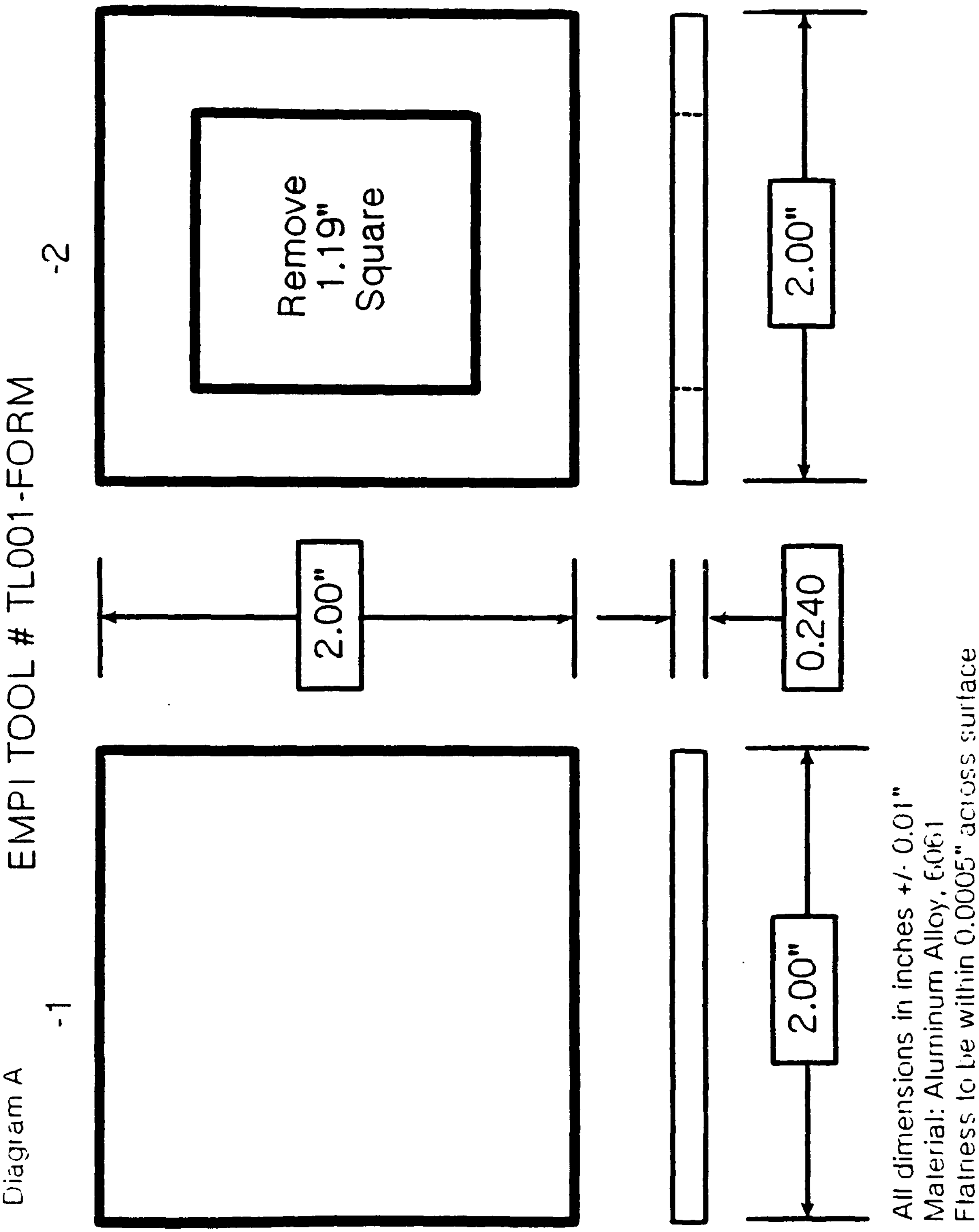


Diagram A
EMPI TOOL # TL001-FORM
-1
-2
Remove
1.19"
Square
2.00"
2.00"
0.240
2.00"
All dimensions in inches +/- 0.01"
Material: Aluminum Alloy, 6061
Flatness to be within 0.0005" across surface

Interoffice Correspondence
TRW Avionics & Surveillance Group

91.Q602.PCC.ST5.1

Subject	Date	From
Detailed Experimental Plan Solder Paste Deposit (ST51)	14 February 1991	J. MURRAY

To	cc	Location/Phone
P. Glaser	D. Cavanaugh P. Finkenbinder P. Crepeau T. Neillo	RC4/1073/3182

This IOC presents the detailed experimental plan and procedures for performing the Sub Task 5, Part 1 experimental procedure. This experiment is designed to identify significant inter-workstation process variables that affect several responses for the solder paste deposition work cell. The significant process variables were identified in a "brainstorming" session among several manufacturing and process engineers. Figure 1 presents a cause and effect diagram that identifies the process variables and responses for the solder paste deposition work cell. The enclosed process variables are those being evaluated in this experiment. The unenclosed process variables are intrastation variables that were previously evaluated and reported.

Ranges (or levels) for the process variables were selected based on tolerances that were expected to be encountered on the factory floor. These ranges, the instruments used to measure the variables, and the reference to the source for the ranges are presented in Table 1. Double asterisks identify those process variables being evaluated by this experiment. Responses to be analyzed for the solder paste deposition workstation, the instruments used to measure the responses, the specification limits for the responses, and the source for the specification limits are presented in Table 2. This experimental design is a full factorial with three variables. No reflection is required. One replicate will be run, however.

Table 3 presents the form that will be used for each response evaluated by this experimental design. Columns AB, AC, BC, and ABC will be used for interaction effects and experimental error measurements.

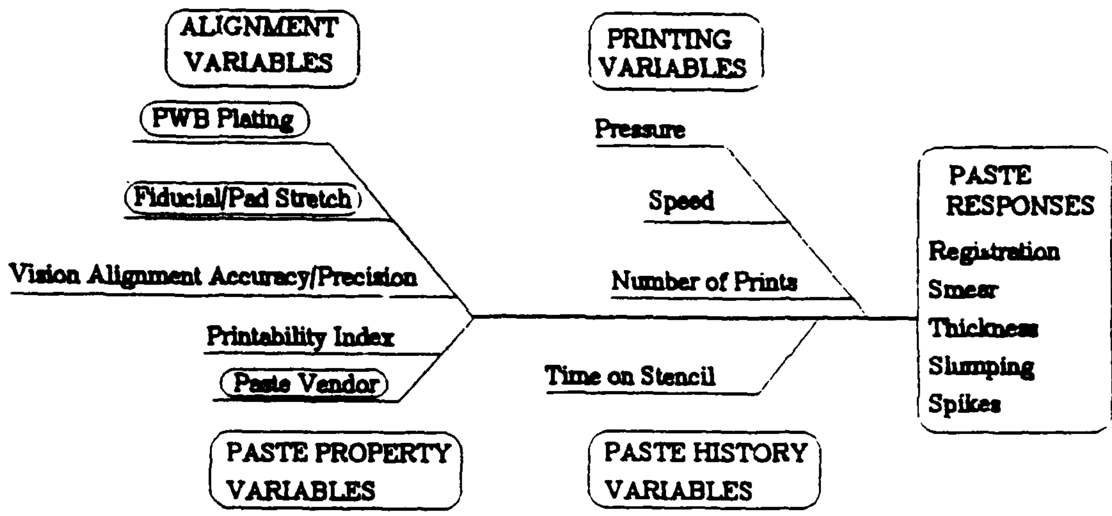


Figure 1. Solder paste deposition cause and effect diagram.

Table 1. Process variable details.

Process Variable	Measuring Device/ Precision	Variable Range	Specification
Squeegee speed	Printer readout/ +/- 0.01-in/min	x.xx - y.yy sec/stroke *	Baseline document
Squeegee pressure	Dial indicator/ +/- 2 psi	x.x - y.y psi *	Baseline document
**Fiducial pad stretch	Coordinatograph +/- 0.1 mil	+3.0 mils from nominal	PWB fabrication drawing
Alignment accuracy/ precision	Microscope with filar/ +/- 0.1 mil	+/- 1.5-mil from nominal	Baseline document
Time on stencil	Timer/ +/- 1-min	0 to 33 hrs	Baseline document
Printability index	Microscope with filar/ +/- 0.1-mil	N/A	Baseline document
Number of prints	Manual count +/- 0	1 to 5	Baseline document
**PWB plating	Inspection/ +/- 0	Reflowed tin-lead and solder dipped/hot air leveled	MEAD Design options
**Solder paste vendor	Inspection/ +/- 0	Metech RF63 and Multicore Sn62-RM92A90	MEAD solder paste study

* Depends on viscosity of solder paste used.
** Process variables being studied by this experiment.

Table 2. Response variable details.

Response Variable	Measuring Device/ Precision	Specification Limit	Specification
Registration	Microscope with filar/ +/- 0.1-mil	deposit overhang </=25% of pad axis in direction measured	MM para. 2-1
Smear	Microscope with filar/ +/- 0.1-mil	print separation >25% of design spacing	MM para. 2.3
Thickness	Microscan/ +/- 0.1-mil	+/- 20% of stencil thick. at location measured.	MM para. 2.5
Slumping	Microscope with filar/ +/- 0.1-mil	print separation >25% of design spacing.	MM para. 2.7
Spikes	Microscan +/- 0.1-mil	<1 times 't' of stencil thick at location measured.	MM para. 2.7

Table 3. Response table with interaction effects.

Random Order Trial Number	Standard Order Trial Number	Response Observed Value	A		B		C		AB		AC		BC		ABC	
			1	2	1	2	1	2	1	2	1	2	1	2	1	2
	1															
	2															
	3															
	4															
	5															
	6															
	7															
	8															
TOTAL																
NUMBER OF VALUES																
AVERAGE																
EFFECT																

II. MATERIALS AND SUPPLIES

PWB

Qty	P/N	Description
6	786582A SN 5, 6, 7, 8, 11, 13	Solder dipped, hot air leveled, no fiducial stretch, normal thickness
7	786582B SN 54, 63, 70, 73, 79, 80, 81	Solder dipped, hot air leveled, max fiducial stretch, normal thickness
7	786582C SN 103, 104, 111, 120, 125, 127, 134	Fused Sn/Pb., no fiducial stretch, normal thickness
6	786582D SN 168, 169, 171, 173, 174, 184	Fused Sn/Pb, maximum fiducial stretch, normal thickness

Solder paste

Metech RHF63	Metech, Inc. Route 401 Halverson, PA 19520
Multicore SN62RM92A90	Multicore Solders Cantiague Rock Road Westbury, NY 11590

Stencil

T-786582-6/1 T-786582-6/2	6/12 mil thickness

Miscellaneous

Palette knife, plastic Bristle brush	Holbein

Shamis 99-150 cleaning cloth	Affiliated Manufacturers. Inc.
96244 Protective gloves	Jones Associates

Solvents

Isopropyl alcohol	TT-I-335
1.1.1-Trichlorethane	MIL-T-81533

III. TOOLS AND EQUIPMENT

General purpose stereo microscope. 0.7x-3x zoom with an American Optical No. 424. 10x-filar eyepiece.

Screen Printer No. 24-ASP	MPM Corp. 10 Forge Park Franklin. MA 02038
Malcom Viscometer	Austin America Technology 12201 Technology Blvd Austin. TX 78727
Vapor degreaser. CBL-18	Baron-Blakeslee. Inc. 2001 N. Janice Ave. Melrose Park. IL 60160
Stencil Cleaner	Tooltronics. Inc. 710 Ivy Street Glendale. CA 91204
Microscan	Cyber Optics Corp. 2331 University Ave. SE Minneapolis. MN 55414

IV PROCEDURE

A.

1. Select one 786582A/B and one 786582C/D PWBs that have fiducial-to-fiducial dimensions that are closest to the drawing nominal Mark these as stencil set-up PWBs. Use a coordinatograph with a precision of +/- 0.1-mil. max.. precision to make this determination, and record the numbers

2. Select two additional 786582A/B and two 786582C/D PWBs that have minimum fiducial-to-fiducial dimensions. Serialize these as 786582A, SNs 101 and 102, and 786582C, SNs 301 and 302. Use a coordinatograph with a +/- 0.1-mil, max., precision to make this determination, and record the numbers.

3. Select two 786582B/A and two 786582D/C PWBs that have maximum fiducial-to-fiducial dimensions. Serialize these as 786582B, SNs 201 and 202 and 786582D, SNs 401 and 402, respectively. Use a coordinatograph with a +/- 0.1-mil, max., precision to make this determination, and record the numbers.

4. The worksheet shown in Table 13 is to be used to run the first (or initial) experimental matrix. One worksheet will be used, per response evaluated (Table 2), to record the value of that response for each run in the experiment. Column A is assigned to the 'Solder Past Vendor', subcolumn 1 is for 'Metech', subcolumn 2 is for 'Multicore'. Column B is assigned to 'Fiducial Stretch', subcolumn 1 is for 'Minimum Stretch', subcolumn 2 is for 'Maximum Stretch'. Column C is assigned to 'PWB Plating Type', subcolumn 1 is for 'Solder Dipped and Hot Air Leveled', subcolumn 2 is for 'Tin/Lead Plate and Fused'. The remaining columns are for experimental error determinations.

5. Use the randomized run numbers in the "Random Order Trial Number" column of Table 13. Sequence the experiment trials using this random number sequence.

6. Clean the serialized PWBs in an in-line solvent cleaner.

7. Set up the ASP-24 stencil printer with the appropriate reference PWBs.

8. Using the combination of solder paste vendor, fiducial stretch PWB, and plating finish required required by Table 13 for a specific, run print two boards in succession and use the second board to collect data for the five responses listed in Table 2. Repeat, until all eight trials have been run.

9. The trial run order in Table 13 was rerandomized and incorporated into the Table 14 worksheet. Using this new experimental matrix, rerun the experiment as was done in paragraphs 1 through 8, above. This will result in a replicated set of data which will enable variability statistics to be determined.

V. RESPONSE DATA

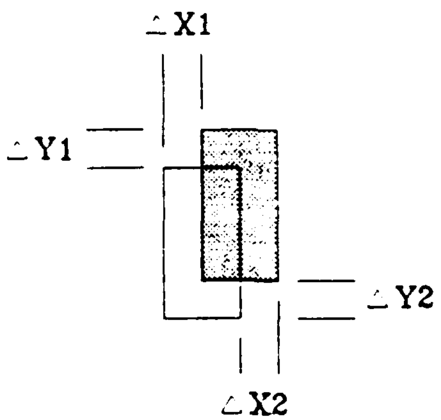
A. Registration

1. Measure the solder paste deposit delta x(1), delta x(2), delta y(1), and delta y(2) misregistration for each of 8 runs at the locations listed in Table 4. Use a filar eyepiece on a microscope with a precision of at least +/- 0.1-mil.

Table 4. Solder paste misregistration.

RUN NO. ________ DATE ________

COMPONENT	PAD	△X1	△X2	△Y1	△Y2
U7	30				
U7	31				
U7	32				
U2	01				
U2	02				
U2	03				
U30	01				
U30	02				
U30	03				
U34	13				
U34	14				
U34	15				
U33	14				
U33	15				
U33	16				



B. Smears

1. Visually scan the fine pitch device footprints (U1, 20, and 39) that are parallel to the squeegee blade (x-direction). Measure and record a paste smear condition that represents 80 percent of the pads and one that represents a worst case condition. Use a microscope with a filar eyepiece with a minimum precision of +/- 0.1 mils.

2. Repeat B.1. above, for paste deposits that are perpendicular to the squeegee blade (y-direction).

3. Visually scan the 50-mil pitch LCC device footprints that are parallel to the squeegee blade (x-direction). Measure and record a paste smear condition that represents 80 percent of the pads and one that represents a worst case condition. Use a microscope with a filar eyepiece with a minimum precision of +/- 0.1 mils.

4. Repeat B.3. above, for paste deposits that are perpendicular to the squeegee blade (y-direction).

C. Thickness

1. Measure the solder paste thickness for each of 8 runs at the locations listed in Table 6. Use a Microscan with a precision of 0.1-mil max. This represents the 50-mil pitch LCC component footprints.

2. Repeat C.1 above, using Table 7. This represents the 25-mil pitch fine pitch device footprints.

3. Repeat C.1 above, using Table 8. This represents the CWR06 chip component footprints.

4. Repeat C.1 above, using Table 9. This represents the CDR02 chip component footprints.

Table 6. Solder paste deposit thickness 50-mil pitch LCCs.

		Orientation		
Component	Pad	Hor	Vert	Thickness
U2	1		X	
	2		X	
	3		X	
		avg vert	______	
		X		
		X		
		X		
		avg horiz	______	
U7	27	X		
	28	X		
	29	X		
		avg horiz	______	
	30		X	
	31		X	
	32		X	
		avg vert	______	
U38	27	X		
	28	X		
	29	X		
		avg horiz	______	
	30		X	
	31		X	
	32		X	
		avg vert	______	
U34	27	X		
	28	X		
	29	X		
		avg horiz	______	
	30		X	
	31		X	
	32		X	
		avg vert	______	

Table 6. Solder paste deposit thickness 50-mil pitch LCCs (concluded)

Component	Pad	Orientation Hor	Orientation Vert	Thickness
U19	16		X	
	17		X	
	18		X	
		avg vert	______	
	19	X		
	20	X		
	1	X		
		avg horiz	______	

Table 7. Solder paste deposit thickness fine pitch devices.

Component	Pad	Orientation Hor	Orientation Vert	Thickness
U1	1	X		
	2	X		
	3	X		
	avg			------
	130		X	
	131		X	
	132		X	
	avg			------
U20	1	X		
	2	X		
	3	X		
	avg			------
	130		X	
	131		X	
	132		X	
	avg			------
U39	97	X		
	98	X		
	99	X		
	avg			------
	100		X	
	101		X	
	102		X	
	avg			------

Table 8. Solder paste deposit thickness CWR06 components.

Component	Pad	Thickness
C43	1	
	2	
C46	1	
	2	
C48	1	
	2	
avg		______

Table 9. Solder paste deposit thickness CDR02 components.

Component	Pad	Thickness
C2	1	
	2	
C4	1	
	2	
C6	1	
	2	
	avg	______
C19	1	
	2	
C20	1	
	2	
C27	1	
	2	
	avg	______
C32	1	
	2	
C39	1	
	2	
C42	1	
	2	
	avg	______

5. Repeat C.1 above, using Table 10. This represents the RM0705 chip component footprints.

D. Slumping

1. Visually scan the fine pitch device footprints (U1, 20, and 39) that are parallel to the squeegee blade (x-direction). Measure and record, on a worksheet similar to that shown in Table 11, a paste slump condition that represents 80 percent of the pads and one that represents a worst case condition. Use a microscope with a filar eyepiece with a minimum precision of +/- 0.1 mils.

2. Repeat B.1, above, for paste deposits that are perpendicular to the squeegee blade (y-direction).

3. Visually scan the 50-mil pitch LCC device footprints that are parallel to the squeegee blade (x-direction). Measure and record, on a worksheet similar to that shown in Table 11, a paste slump condition that represents 80 percent of the pads and one that represents a worst case condition. Use a microscope with a filar eyepiece with a minimum precision of +/- 0.1 mils.

4. Repeat B.3, above, for paste deposits that are perpendicular to the squeegee blade (y-direction).

E. Spikes

1. Visually scan the fine pitch device footprints (U1, 20, and 39) that are parallel to the squeegee blade (x-direction). Measure and record, on a worksheet similar to that shown in Table 12, a paste spike condition that represents 80 percent of the pads and one that represents a worst case condition. Use a microscope with a filar eyepiece with a minimum precision of +/- 0.1 mils.

2. Repeat B.1, above, for paste deposits that are perpendicular to the squeegee blade (y-direction).

3. Visually scan the 50-mil pitch LCC device footprints that are parallel to the squeegee blade (x-direction). Measure and record, on a worksheet similar to that shown in Table 12, a paste spike condition that represents 80 percent of the pads and one that represents a worst case condition. Use a microscope with a filar eyepiece with a minimum precision of +/- 0.1 mils.

4. Repeat B.3, above, for paste deposits that are perpendicular to the squeegee blade (y-direction).

VI. DATA REDUCTION

Using the data gathered by this experiment, the response sheets typified by Tables 13 and 14 will be completed for each response; and significant interstation process variables will be identified.

Additional statistical analyses of the data using analysis of variance (ANOVA) techniques will yield variability, experimental error, and process capability indices data.

Table 10. Solder paste deposit thickness RM0705 components.

Component	Pad	Thickness
R1	1	
	2	
R3	1	
	2	
R6	1	
	2	
	avg	------
R34	1	
	2	
R29	1	
	2	
R25	1	
	2	
	avg	------

Table 5

Smear on Component Pads

INITIAL RUN: ____
REPLICATE RUN: ____ DATE ________

	X 50-MIL PITCH		Y 50-MIL PITCH		X FINE PITCH		Y FINE PITCH	
RUN	80%	MAX	80%	MAX	80%	MAX	80%	MAX
1								
2								
3								
4								
5								
6								
7								
8								

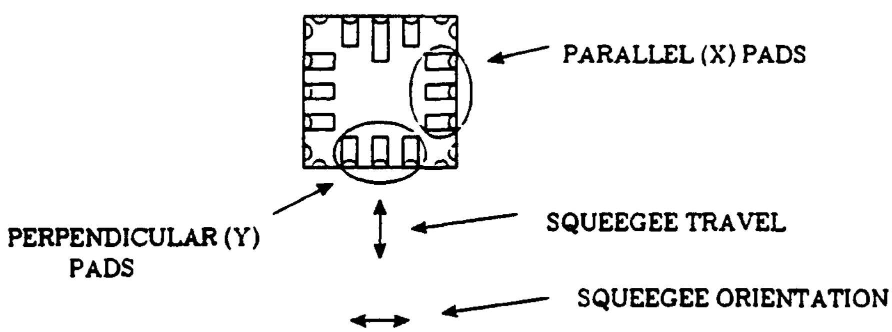


Table 11

Slump on Component Pads

INITIAL RUN: ____
REPLICATE RUN: ____ DATE __________

	X 50-MIL PITCH		Y 50-MIL PITCH		X FINE PITCH		Y FINE PITCH	
RUN	80%	MAX	80%	MAX	80%	MAX	80%	MAX
1								
2								
3								
4								
5								
6								
7								
8								

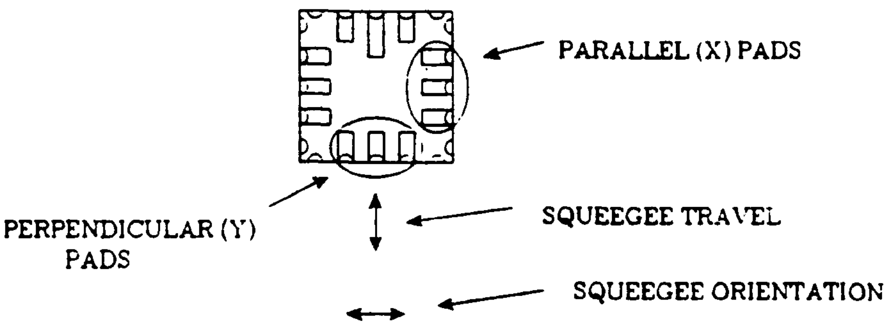


Table 12

Spikes on Component Pads

INITIAL RUN: ____
REPLICATE RUN: ____ DATE ________

	X 50-MIL PITCH		Y 50-MIL PITCH		X FINE PITCH		Y FINE PITCH	
RUN	80%	MAX	80%	MAX	80%	MAX	80%	MAX
1								
2								
3								
4								
5								
6								
7								
8								

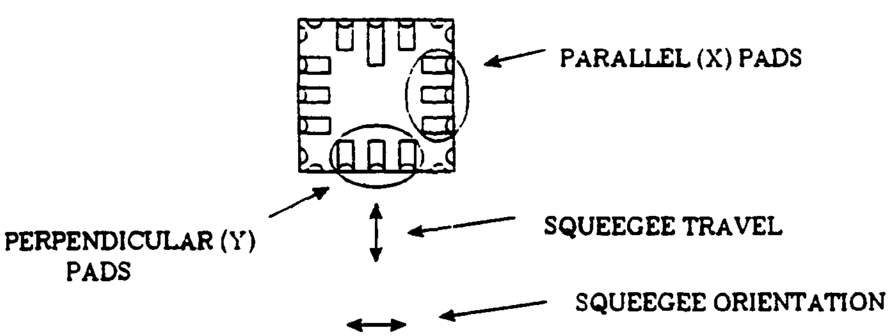


Table 13

Initial Experimental Run

Random Order Trial Number	Standard Order Trial Number	PWB Serial Number	A Solder Paste Vendor		B Fiducial Stretch mils		C PWB Style		AB — INTERACTION AND ERROR TERMS —		AC		BC		ABC		RESPONSE
			1	2	1	2	1	2	1	2	1	2	1	2	1	2	
7	1	A-26	Met		0		fused										
1	2	C-106	Met		0			air									
8	3	C-131	Met			+3	fused										
3	4	A-30	Met			+3		air									
2	5	B-60		Multi	0		fused										
6	6	D-155		Multi	0			air									
5	7	D-157		Multi		+3	fused										
4	8	B-65		Multi		+3		air									

Table 14

Replicate Experimental Tun

Random Order Trial Number	Standard Order Trial Number	PWB Serial Number	A Solder Paste Vendor		B Fiducial Stretch mils		C PWB Style		AB		AC		BC		ABC		RESPONSE
			INTERACTION AND ERROR TERMS														
			1	2	1	2	1	2	1	2	1	2	1	2	1	2	
2	1	A-26	Met		0		fused										
6	2	C-106	Met		0			air									
8	3	C-131	Met			+3	fused										
1	4	A-30	Met			+3		air									
7	5	B-60		Multi	0		fused										
3	6	D-155		Multi	0			air									
5	7	D-167		Multi		+3	fused										
4	8	B-66		Multi		+3		air									

Interoffice Correspondence
TRW Avionics & Surveillance Group

91.Q602.PCC.ST5.2

Subject	Date	From
Detailed Experimental Plan Component Placement (ST52)	26 January 1991	P. CREPEAU
To	**cc**	**Location/Phone**
P. Glaser	D. Cavanaugh P. Finkenbinder J. Murray T. Neillo	RC4/1073/3182

I. INTRODUCTION

This IOC presents the detailed experimental plan and procedures for performing the Sub Task 5, Part 2 experimental procedure. This experiment is designed to identify significant inter-workstation process variables that effect several responses for the component placement work cell. The significant process variables were identified in a "brainstorming" session among several manufacturing and process engineers. Figure 1 presents a cause and effect diagram that identifies the process variables and responses for the component placement work cell. The shaded process variables are those being evaluated in this experiment. The, unshaded process variables are intrastation variables that were previously evaluated and reported.

Ranges (or levels) for the process variables were selected based on tolerances that were expected to be encountered on the factory floor. These ranges, the instruments used to measure the variable ranges, and the reference to the source for the ranges are presented in Table 1. Double asterisks identify those process variables being evaluated by this experiment. Responses to be analyzed for the component placement workstation, the instruments used to measure the responses, the specification limits for the responses, and the source for the specification limits are presented in Table 2. The main experimental design is an eight run fractional factorial with five variables. One reflection is required.

Table 3 presents the form that will be used for each response evaluated by this experimental design. Columns BC and ABC will be used for experimental error measurements.

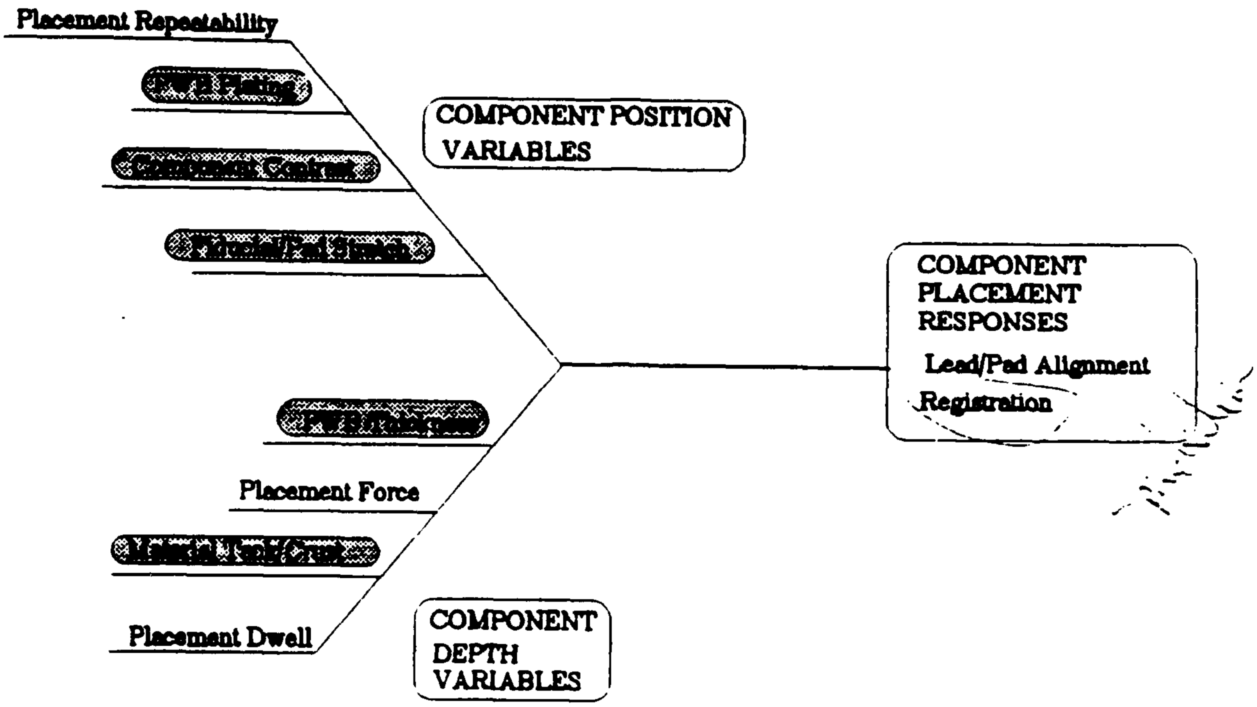


Figure 1. Component placement cause and effect diagram.

Table 1. Process variable details.

Process Variable	Measuring Device/ Precision	Variable Range	Specification
Placement repeatability	Microscope with filar/ +/- 0.1-mil	0 2mils	Baseline document
**Solder paste open time	Timer/ +/- 1 sec	0.5 to 3 hrs	Assembly staging time
**PWB plating	Inspection/ +/- 0	Reflowed tin/ lead and solder dipped/hot air leveled	MEAD design options
**Tinned lead aging	Steam ager/ +/- 1 minute	0 to 6 hours	Engineering judgment
**Fiducial pad stretch	Coordinatograph/ +/- 0.1-mil	+/- 3 mils from nominal	PWB fabrication drawing
Placement force	Robot/ +/- 1 gram	5gm to 50gm per lead	TRW placement study
**PWB thickness	Dial micrometer/ +/- 0.1-mil	58 to 68 mils	PWB fabrication drawing

**Process variables being studied by this experiment.

Table 2. Response variable details.

Response Variable	Measuring Device/ Precision	Specification Limit	Specification
Lead/pad alignment	Microscope with filar +/- 0.1-mil		MIL-STD-2000
Chip component overhang		10% of termination width, max	
Lap		5-mil, max	
Lead and toe overhang		25% of lead width, max or 20 mils, max: whichever is greater	
Heel clearance		100% of lead width	
Leadless chip carrier overhang		25% of castellation width, max	MM 3.3
Lead penetration into solder paste	Microscan/ 0.1-mil	No air gap to 3 mils	MEAD placement study

Table 3. Response table with interaction effects.

Random Order Trial Number	Standard Order Trial Number	Response Observed Values	A		B		C		AB		AC		BC		ABC	
			1	2	1	2	1	2	1	2	1	2	1	2	1	2
	1															
	2															
	3															
	4															
	5															
	6															
	7															
	8															
TOTAL																
NUMBER OF VALUES																
AVERAGE																
EFFECT																

II. MATERIALS AND SUPPLIES

PWB

Qty	P/N	Description
4	786582G	Fused tin/lead, thin, nominal fiducial
4	786582H	Fused tin/lead, thick, nominal fiducial

Component

Qty	P/N	Description
48	IMKX3F1-4546AA	132-pin FPD
288	PB-C85124	20-pin LCC
160	PB-44823	28-pin LCC
128	IRK32F1-200B	32-pin RLCC
608	M55342K06B-110BR	M55342/6 chip resistor
672	CDR02BX103BKURT	CDR02 chip capacitor
96	49BCP	CWR06 chip capacitor

Solder paste

Metech RHF63	Metech, Inc. Route 401 Halverson, PA 19520

Stencil

T-786582-6/1	6/12 thickness
T-786582-6/2	

Miscellaneous

Palette knife, plastic	Holbein
Shamis, 99-150 cleaning cloth	Affiliated manufacturers
Bristle brush	
Protective gloves	Jones Associates

Solvents

Isopropyl alcohol	TT-I-335
1.1.1-trichlorethane	MIL-T-81533

III. TOOLS AND EQUIPMENT

General purpose stereo microscope. 0.7x-3x zoom with an American Optical No. 424. 10x-filar eyepiece.

Screen Printer No. 24-ASP	MPM Corp. 10 Forge Park Franklin. MA 02035
Malcom Viscometer	Austin American Technology 12201 Technology Blvd Austin. TX 78727
In-Line Cleaner. CBL-18	Baron-Blakeslee. Inc. 2001 N. Janice Ave. Melrose Park. IL 60160
Stencil Cleaner	Tooltronics. Inc. 710 Ivy Street Glendale. CA 91204
Microscan	CyberOptics Corp. 2331 University Ave.. SE Minneapolis. MN 55414
Robotic Workcell	Gelzer Systems 425 Enterprise Drive Westerville. OH 43081
Steam Aging Cabinet	MountainGate Engineering 1510 Dell Ave. Campbell. CA 95008

IV. PROCEDURE

A.

1. Select four 786582G, 786582H, 786582M, and 786582N PWBs that have minimum fiducial-to-fiducial dimensions. Serialize as 786582G, SNs 701-704; 786582H, SNs 801-804; 786582M, SNs 1301-1304; and 786582N, SNs 1401-1404.

2. Select from 786582I, 786582J, 786582K, and 786582L PWBs that have maximum fiducial-to-fiducial dimensions. Serialize as 786582I, SNs 901-904; 786582J, SNs 1001-1004; 786582K, SNs 1101-1104; and 786582L, SNs 1201-1204.

3. Create one worksheet, similar to the one shown in Table 3, for each of the two responses listed in Table 2 that are to be monitored. Column A is assigned to 'Tinned Lead Aging', subcolumn 1 is for 'Zero Aging', subcolumn 2 is for '6 month Aging'. Column B is assigned to 'PWB Type'; subcolumn 1 is for ' Slder Dipped and Hot Air Leveled', subcolumn 2 is for 'Tin/Lead Plate and Fused'. Column C is assigned to 'Solder Paste Open Time', subcolumn 1 is for '0.5-Hour Open Time' subcolumn 2 is for '3-Hour Open Time'. Column AB is assigned to 'PWB Thickness', subcolumn 1 is for 'Thin', subcolumn is for 'Thick'. Column AC is assigned to 'Fiducial Stretch', subcolumn 1 is for 'Minimum Stretch', subcolumn 2 is for 'Maximum Stretch'. The remaining columns are for experimental error.

4. Randomize the "Standard Order Trial Number" column and enter the appropriate random number in the "Random Order Trial Number" column. Run the experimental trials using the random number sequence.

5. Clean the serialized PWBs in the in-line solvent cleaner.

6. Set up the 24-ASP stencil printer with an appropriate reference PWB.

7. Set up the placement side of the Gelzer robot. Make sure there are sufficient properly prepared components for the experiments that are to be performed.

8. Using the Metech solder paste, print the appropriate PWB for the experiment to be performed. Visually inspect the deposit and measure the deposit thickness with the Microscan to assure the quality of the deposit.

9. After allowing for any "open time", place the components on the posted PWB with the robot.

10. Repeat steps 8 and 9 until all 8 experiments have been completed.

11. Swap the shaded cells between the '1' and '2' subcolumns of each of the 7 process variable columns (e.g., column A1 for runs 1-4 will be shaded rather than clear and column A2 for runs 5-8 will be shaded rather than clear).

13. Rerandomize the run order number and rerun the experimental matrix with the inverted process variable ranges. This will result in a reflected set of data which will isolate interaction effects that might mask the main effects of the process variables assigned to column AB and AC.

V. RESPONSE DATA

A. Lead/Pad Alignment

1. Measure the fine pitch component lead placement lateral misregistration for each of the 8 experimental runs at the locations listed in Table 4. Use a filar eyepiece on a microscope with a precision of at least 0.1-mil.

2. Measure the 20-pin LCC component termination placement lateral misregistration for each of the 8 experimental runs at the locations listed in Table 5. Use a filar eyepiece on a microscope with a precision of at least 0.1-mil.

3. Measure the 28-pin LCC component termination placement lateral misregistration for each of the 8 experimental runs at the locations listed in Table 6. Use a filar eyepiece on a microscope with a precision of at least 0.1-mil.

4. Measure the 32-pin LCC component termination placement lateral misregistration for each of the 8 experimental runs at the locations listed in Table 7. Use a filar eyepiece on a microscope with a precision of at lease 0.1-mil.

Table 4. Fine pitch device placement misregistration.

Component	Pad	Orientation Hor	Vert	Lateral Displacement
U1	130		X	
	131		X	
	132		X	
			avg	
	1	X		
	2	X		
	3	X		
			avg	
	64		X	
	65		X	
	66		X	
			avg	
	67	X		
	68	X		
	69	X		
			avg	
U20	130		X	
	131		X	
	132		X	
			avg	
	1	X		
	2	X		
	3	X		
			avg	
	64		X	
	65		X	
	66		X	
			avg	

Table 4. Fine pitch device placement misregistration (concluded)

Component	Pad	Orientation Hor	Vert	Lateral Displacement
	67	X		
	68	X		
	69	X		
			avg	
U39	130		X	
	131		X	
	132		X	
			avg	
	1	X		
	2	X		
	3	X		
			avg	
	64		X	
	65		X	
	66		X	
			avg	
	67	X		
	68	X		
	69	X		
			avg	

Table 5. 20-pin LCC device placement misregistration.

Component	Pad	Orientation Hor	Vert	Lateral Displacement
U2	1		X	
	2		X	
	3		X	
			avg	
	4	X		
	5	X		
	6	X		
			avg	
	11		X	
	12		X	
	13		X	
			avg	
	14	X		
	15	X		
	16	X		
			avg	
U5	1	X		
	2	X		
	3	X		
			avg	
	4	X		
	5	X		
	6	X		
			avg	
	11		X	
	12		X	
	13		X	
			avg	

Table 5. 20-pin LCC device placement misregistration (continued)

Component	Pad	Orientation Hor	Vert	Lateral Displacement
	14	X		
	15	X		
	16	X	avg	
U19	1		X	
	2		X	
	3		X	
			avg	
	4	X		
	5	X		
	6	X		
			avg	
	11		X	
	12		X	
	13		X	
			avg	
	14	X		
	15	X		
	16	X		
			avg	
U28	1	X		
	2	X		
	3	X		
			avg	
	4	X		
	5	X		
	6	X		
			avg	
	11	X		
	12	X		
	13	X		
			avg	

Table 5. 20-pin LCC device placement misregistration (concluded)

Component	Pad	Orientation Hor	Vert	Lateral Displacement
	14	X		
	15	X		
	16		X	
			avg	
U33	1		X	
	2		X	
	3		X	
			avg	
	4	X		
	5	X		
	6	X		
			avg	
	11		X	
	12		X	
	13		X	
			avg	
	14	X		
	15	X		
	16	X		
			avg	

Table 6. 28-Pin LCC placement misregistration.

Component	Pad	Orientation Hor	Vert	Lateral Displacement
U22	2		X	
	3		X	
	4		X	
			avg	
	5	X		
	6	X		
	7	X		
			avg	
	16		X	
	17		X	
	18		X	
			avg	
	19	X		
	20	X		
	21	X		
			avg	
U31	2		X	
	3		X	
	4		X	
			avg	
	5	X		
	6	X		
	7	X		
			avg	
	16		X	
	17		X	
	18		X	
			avg	

Table 6. 28-Pin LCC placement misregistration (concluded)

Component	Pad	Orientation Hor	Vert	Lateral Displacement
	19	X		
	20	X		
	21	X		
			avg	
U35	2		X	
	3		X	
	4		X	
			avg	
	5	X		
	6	X		
	7	X		
			avg	
	16		X	
	17		X	
	18		X	
			avg	
	19	X		
	20	X		
	21	X		
			avg	

Table 7. 32-pin LCC device placement misregistration.

Component	Pad	Orientation Hor	Vert	Lateral Displacement
U7	2		X	
	3		X	
	4		X	
			avg	
	5	X		
	6	X		
	7	X		
			avg	
	18		X	
	19		X	
	20		X	
			avg	
	21	X		
	22	X		
	23	X		
			avg	
U14	2		X	
	3		X	
	4		X	
			avg	
	5	X		
	6	X		
	7	X		
			avg	
	18		X	
	19		X	
	20		X	
			avg	

Table 7. 32-pin LCC device placement misregistration (concluded)

Component	Pad	Orientation Hor	Vert	Lateral Displacement
	21	X		
	22	X		
	23	X		
			avg	
U34	2		X	
	3		X	
	4		X	
			avg	
	5	X		
	6	X		
	7	X		
			avg	
	18		X	
	19		X	
	20		X	
			avg	
	21	X		
	22	X		
	23	X		
			avg	

5. Measure the chip component termination placement lateral and end-to-end misregistration for each of the 8 experimental runs at the locations listed in Table 8. Use a filar eyepiece on a microscope with a precision of at least 0.1-mil.

B. Lead Penetration

1. Measure the penetration of the fine pitch device leads into the solder paste deposit for each of the eight experimental runs at the locations listed in Table 9. Use a Microscan and measure the solder paste height, as deposited, at the indicated locations (A). Use a micrometer to measure the appropriate fine pitch device lead thicknesses (B) prior to placement. Use a Microscan to measure the dimension from the PWB to the top of the placed fine pitch device lead (C). Lead penetration will equal A+B-C. Measurements shall be to a precision of 0.1-mil. min.

2. Measure the penetration of the 20-pin LCC terminations into the solder paste deposit for each of the eight experimental runs at the locations listed in Table 10. Use a Microscan and measure the solder paste height, as deposited, at the indicated locations (A). Use a micrometer to measure the appropriate package thickness (B) prior to placement. Use a Microscan to measure the dimension from the PWB to the top of the LCC package (C). Penetration will equal A+B-C. Measurements shall be to a precision of 0.1-mil. min.

3. Measure the penetration of the 28-pin LCC terminations into the solder paste deposit for each of the eight experimental runs at the locations listed in Table 11. Use the same technique as in 2. above.

Table 8. Chip device placement misregistration.

Component	Pad	Lateral ΔX	ΔY	Package Style
C43	1			CWR06
	2			
	1,2			
C46	1			CWR05
	2			
	1,2			
C48	1			CWR06
	2			
	1,2			
C2	1			CDR02
	2			
	1,2			
C7	1			CDR02
	2			
	1,2			
C26				CDR02
	2			
	1,2			
C36	1			CDR02
	2			
	1,2			
E42	1			CDR02
	2			
	1,2			
R1	1			M55342/6
	2			
	1,2			

Table 8. Chip device placement misregistration (concluded)

Component	Pad	Lateral ΔX	Lateral ΔY	Package Style
R12	1			M55342/6
	2			
	1.2			
R30	1			M55342/6
	2			
	1.2			
R34	1			M55342/6
	2			
	1.2			
R25	1			M55342/6
	2			
	1.2			

Table 9. Fine pitch device lead penetration.

Component	Thickness Pad	Paste	Lead	Placed Lead
U1	1			
	2			
	3			
	avg			
	34			
	35			
	36			
	avg			
	67			
	68			
	69			
	avg			
	100			
	101			
	102			
	avg			
U20	1			
	2			
	3			
	avg			
	34			
	35			
	36			
	avg			
	67			
	68			
	69			
	avg			
	100			
	101			
	102			
	avg			

Table 9. Fine pitch device lead penetration (concluded)

Component	Pad	Thickness Paste	Lead	Placed Lead
U39	1			
	2			
	3			
	avg			
	34			
	35			
	36			
	avg			
	67			
	68			
	69			
	avg			
	100			
	101			
	102			
	avg			

Table 10. 20-pin LCC device component penetration.

		Thickness		
Component	Pad	Paste	Lead	Placed Lead
U2	20			
	1			
	2			
	avg			
	5			
	6			
	7			
	avg			
	10			
	11			
	12			
	avg			
	15			
	16			
	17			
	avg			
U5	20			
	1			
	2			
	avg			
	5			
	6			
	7			
	avg			
	10			
	11			
	12			
	avg			
	15			
	16			
	17			
	avg			

Table 10. 20-pin LCC device component penetration (concluded)

	Thickness			
Component	Pad	Paste	Lead	Placed Lead
U19	20			
	1			
	2			
	avg			
	5			
	6			
	7			
	avg			
	10			
	11			
	12			
	avg			
	15			
	16			
	17			
	avg			

Table 11. 28-pin LCC device component penetration.

Component	Pad	Thickness Paste	Lead	Placed Lead
U22	28			
	1			
	2			
	avg			
	6			
	7			
	8			
	avg			
	13			
	14			
	15			
	avg			
	20			
	21			
	22			
	avg			
U31	28			
	1			
	2			
	avg			
	6			
	7			
	8			
	avg			
	13			
	14			
	15			
	avg			
	20			
	21			
	22			
	avg			

Table 11. 28-pin LCC device component penetration (concluded)

		Thickness		
Component	Pad	Paste	Lead	Placed Lead
U35	28			
	1			
	2			
	avg			
	6			
	7			
	8			
	avg			
	13			
	14			
	15			
	avg			
	20			
	21			
	22			
	avg			

Table 12. 32-pin LCC device component penetration.

	Thickness			
Component	Pad	Paste	Lead	Placed Lead
U7	32			
	1			
	2			
	avg			
	8			
	9			
	10			
	avg			
	16			
	17			
	18			
	avg			
	24			
	25			
	26			
	avg			
U14	32			
	1			
	2			
	avg			
	8			
	9			
	10			
	avg			
	16			
	17			
	18			
	avg			
	24			
	25			
	26			
	avg			

Table 12. 32-pin LCC device component penetration (concluded)

Component	Pad	Thickness Paste	Lead	Placed Lead
U34	32			
	1			
	2			
	avg			
	8			
	9			
	10			
	avg			
	16			
	17			
	18			
	avg			
	24			
	25			
	26			
	avg			

4. Measure the penetration of the 32-pin LCC terminations into the solder paste deposit for each of the eight experimental runs at the locations listed in Table 12. Use the same techniques as in 2, above.

5. Measure the penetration of the CWR06 terminations into the solder paste deposit for each of the eight experimental runs at the locations listed in Table 13. Use a Microscan and measure the solder paste heights, as deposited, at the indicated locations (A). Use a micrometer to measure the appropriate package thickness (B) prior to placement. Use a Microscan to measure the dimension from the PWB to the top of the CWR06 package (C). Penetration will equal A+B-C. Measurements shall be to a precision of 0.1-mil, min.

6. Measure the penetration of the CDR02 termination into the solder paste deposit for each of the eight experimental runs at the locations listed in Table 13. Use the same technique as in 2, above.

7. Measure the penetration of the M55342/6 termination into the solder-paste deposit for each of the eight experimental runs at the locations listed in Table 13. Use the same techniques as in 2, above.

VI. DATA REDUCTION

Using the data gathered by this experiment, the response sheets typified by Table 3 will be completed for each response; and significant interstation process variables will be identified.

Additional statistical analyses of the data using analysis of variance (ANOVA) techniques will yield variability, experimental error, and process capability indices data.

Table 13. Chip device component penetration.

Component	Thickness Pad	Paste	Lead	Placed Lead
C43	1			
	2			
	avg			
C46	1			
	2			
	avg			
C48	1			
	2			
	avg			
C2	1			
	2			
	avg			
C7	1			
	2			
	avg			
C26	1			
	2			
	avg			
R1	1			
	2			
	avg			
R2	1			
	2			
	avg			

Table 13. Chip device component penetration.

Component	Pad	Thickness Paste	Lead	Placed Lead
R12	1			
	2			
	avg			
R30	1			
	2			
	avg			

GUIDELINES FOR CALCULATING EMPI PROCESS CAPABILITY INDICES

The measuring system developed to understand and quantify the experimental results is based on the process capability indicies (Cp and Cpk) and the percent of variability accounted or (%V). The Cp and Cpk provide a quick measure of the degree of "robustness" or "safety margin" existing within a process and therefore are a key indicator of the ability to obtain and maintain 100% yields. The Cp simply compares the range of tolerances allowed by the product requirements to the range of process tolerances predicted for the process. The Cpk compares the tendency of the process to produce product that falls exactly midway between the limits of the product requirements.

The Cp and Cpk are based on the predicted process tolerance because the actual process limits cannot be determined effectively, meaning that the Cp is only as good as the assumptions and experimental data used to generate it. A "sanity check" is obtained by mathematically manipulating the experimental data to create the %V, which provides an indication of how well the process limits can be predicted. The %V simply compares the predicted process response and the actual observed response during the experiments. Any unknown variables that affect the process during the experiments will be detected by the %V. Therefore, by combining the Cp, Cpk and the %V a meaningful and confident understanding of the process can be obtained.

The Cp and Cpk are calculated from the experimentally determined variable induced process sub-variation (VIPS). Figure A-1 illustrates how a given total process variation may be divided into the individual sub-variations caused by each one of the variables. The number of variables that contribute to the total process variation may range from one (which presents a trivial case) to many. For the multiple variable cases, if all of the variables can be identified and their respective sub-variations can be determined, then it is possible to predict the overall total process variation by combining the individual sub-variations. For multi-variable cases, Figure A-2 illustrates how each one of the sub-variations can be determined for each variable. The experimental runs are performed using the detailed experimental table and forcing the variables to their high and low values as described above. Another way of stating this in mathematical terms is that the experiment evaluates the unknown process relationship, F[X], for each variable, X, at both the upper, Xhi, and lower, Xlo, ends of the variable range to determine the sub-variation in the process caused by that variable, F[Xhi]-F[Xlo]. To calculate the total process variation caused by all of the variables, the individual subvariations, including experimental errors, are combined together. As long as the variables are independent and have a central tendency, they can be combined using the Root Mean Square (RMS) method. The combined total process variation is equal to the square root of the sum of the squares of the individual sub-variations. This is stated in mathematical terms for a number of variables, n, as $\sqrt{\Sigma(F[Xhi]-F[Xlo])^2}$ evaluated from X=1 to X=n.

To calculate the total Cp, the total process variation as calculated above $(\Sigma(F[Xhi]-F[Xlo])^2)^{1/2}$ evaluated from X=1 to X=n) is divided into the difference in the upper and lower specification limits, USL-LSL. This is illustrated in Figure A-3 along with an example from the IR reflow workcell. In the example, the upper and lower specification difference was determined to be 11° C, the results from the experiment run gave sub-variations of $\pm$1.5° C, $\pm$2.4° C, and $\pm$0.7° C, which combine to give a total process variation of 5.8° C. The resulting Cp as calculated is 1.9, or a theoretical "robustness" of 90 percent.

To calculate the Cpk, the total process variation, as calculated above, is divided into twice the difference between the average response and the nearest specification limit. This is illustrated in Figure A-4 along with an example from the IR reflow workcell. In the example, the grand average was determined to be 217°, which, since it is closer to the USL (221°) than the LSL (210° C), determines the Cpk. The resulting Cpk as calculated is 1.4, or a theoretical "robustness" of 40%, which means that the actual distribution is skewed away from the dead center of the specification limits. If the actual distribution were extremely centered, the Cpk would be equal to the Cp, or in this case be equal to 1.9.

$$Cp = \frac{\text{USL-LSL}}{\text{"Total process variation"}} = \frac{\text{USL-LSL}}{\sqrt{\sum_{\text{variable "x"=1}}^{\text{Variable "x"=n}} \left(\begin{array}{l}\text{Sub-variation}\\ \text{caused by vari-}\\ \text{able x or}\\ \text{experimental}\\ \text{error.}\end{array}\right)^2}} = \frac{\text{USL-LSL}}{\sqrt{\sum_{\text{variable "x"=1}}^{\text{Variable "x"=n}} (F[X_{hi}]-F[X_{lo}])^2}}$$

$$\text{USL-LSL} = 221^\circ C - 210^\circ C = \boxed{11^\circ C}$$

$$\text{Calculated } C_p = \frac{\text{USL-LSL}}{\sqrt{\sum_{\text{variable "x"=1}}^{\text{variable "x"=n}} \left(\begin{array}{l}\text{(Sub-variation}\\ \text{caused by varia-}\\ \text{ble x or experi-}\\ \text{mental error.}\end{array}\right)^2}} = \frac{\text{USL-LSL}}{\sqrt{\sum_{\text{variable "x"=1}}^{\text{variable "x"=n}} (F[X_{hi}]-F[X_{lo}])^2}} = \frac{11^\circ C}{5.8^\circ C} = \boxed{1.9}$$

$$\sqrt{\sum_{\text{variable "x"=1}}^{\text{variable "x"=n}} (F[X_{hi}]-F[X_{1p}])^2} = \sqrt{(\pm 1.5^\circ C^2 \pm 2.4^\circ C^2 \pm .7^\circ C^2)} = \boxed{5.8^\circ C}$$

Initial temp $F[X_{hi}]-F[X_{lo}]=\pm 1.5^\circ C$

Emitter temp $F[X_{hi}]-F[X_{lo}]=\pm 2.4^\circ C$

Belt speed $F[X_{hi}]-F[X_{lo}]=\pm .7^\circ C$

Figure A-1 Method for Calculating Cp From USL,LSL and Total Process Variation with Example from IR Reflow Workcell

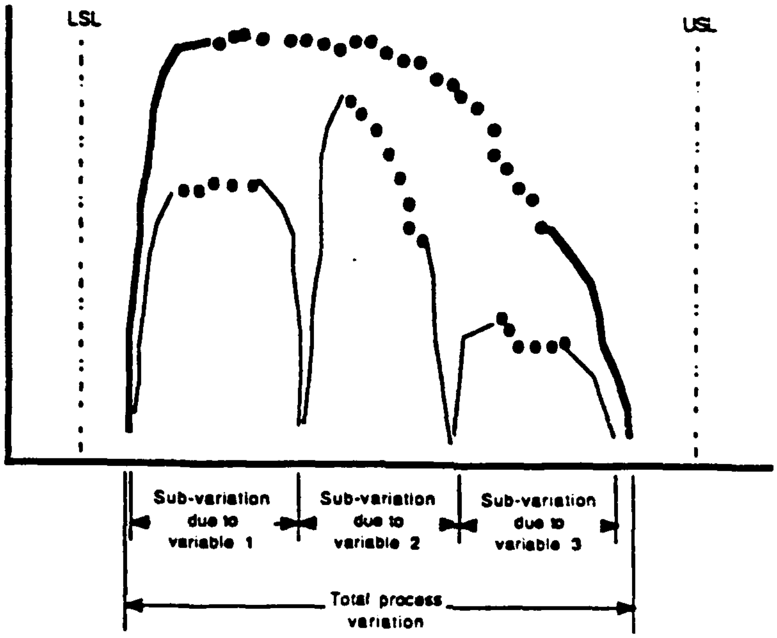


Figure A-2 Method For Determining Total Process Variation By Summing Sub-variations.

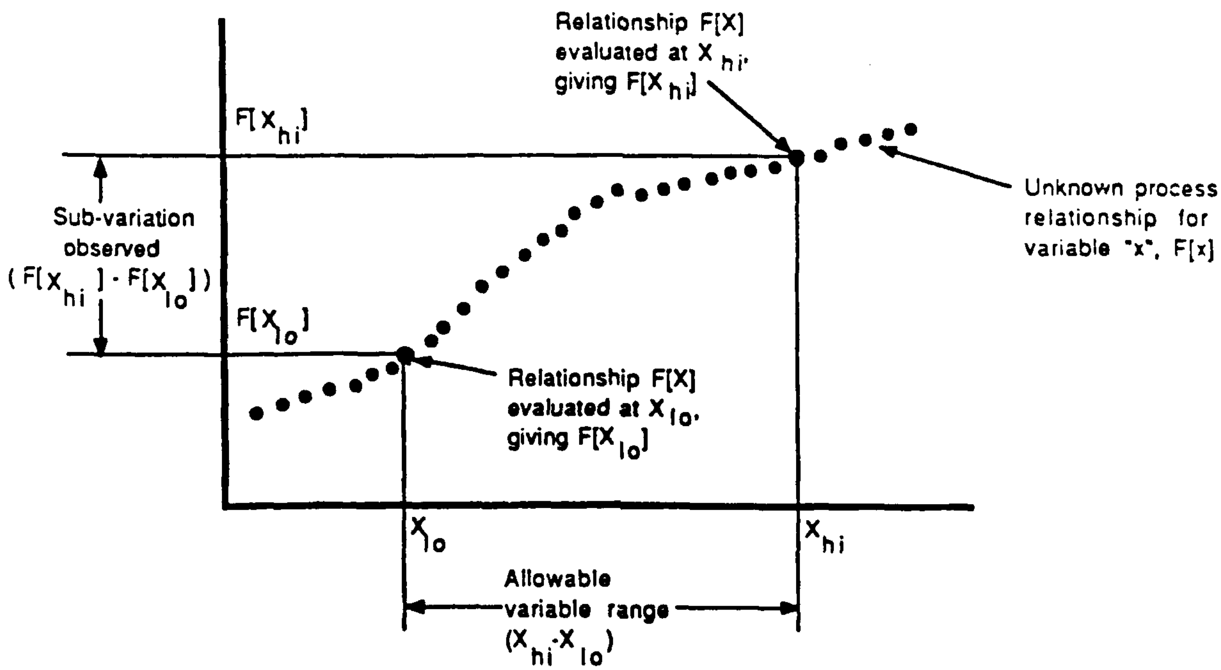


Figure A-3 Method for Determining Sub-variation (F[Xhi]-F[Xlo]) Caused By Variable Range (Xhi-Xlo)

$$\text{Cpk=lesser of}\quad \frac{(USL-\bar{\bar{X}})\times 2}{\text{"Total process Variation"}} = \frac{(USL-\bar{\bar{X}})\times 2}{\sqrt{\sum_{\text{Variable }x=1}^{\text{Variable }x=n}\left(\begin{array}{l}\text{sub-variation}\\ \text{caused by vari-}\\ \text{able }x\end{array}\right)^2}} = \frac{(USL-\bar{\bar{X}})\times 2}{\sqrt{\sum_{\text{Variable }x=1}^{\text{Variable }x=n}(F(X_{hi})-F(X_{lo}))^2}}$$

$$\frac{(\bar{\bar{X}}-LSL)\times 2}{\text{"Total process Variation"}} = \frac{(\bar{\bar{X}}-LSL)\times 2}{\sqrt{\sum_{\text{Variable }x=1}^{\text{Variable }x=n}\left(\begin{array}{l}\text{Subvariation}\\ \text{caused by vari-}\\ \text{able }x\end{array}\right)^2}} = \frac{(\bar{\bar{X}}-LSL)\times 2}{\sqrt{\sum_{\text{Variable }x=1}^{\text{Variable }x=n}(F(X_{hi})-F(X_{lo}))^2}}$$

$$(USL-\bar{\bar{X}})\times 2 = (221^\circ-217)\times 2 = \boxed{8^\circ c}$$

$$\text{Calculated Cpk} = \frac{(USL-\bar{\bar{X}})\times 2}{\sqrt{\sum_{\text{Variable "X"}=1}^{\text{Variable }x=n}\left(\begin{array}{l}\text{Subvaria-}\\ \text{tion caused}\\ \text{by variable }x\\ \text{or experi-}\\ \text{mental error}\end{array}\right)}} = \frac{(USL-\bar{\bar{X}})\times 2}{\sqrt{\sum_{\text{Variable }x=1}^{\text{Variation }x=n}((F(X_{hi})-F(X_{lo}))^2}} = \frac{\boxed{8^\circ c}}{\boxed{5.8^\circ c}} = 1.4$$

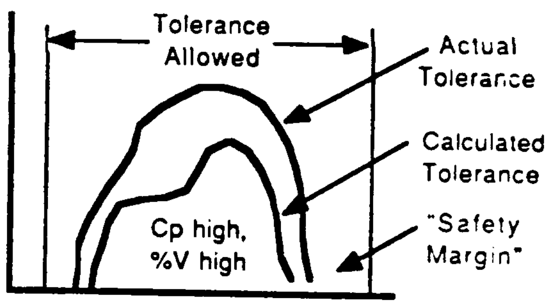
$$\sqrt{\sum_{\text{Variable }x=1}^{\text{Variable }x=n}((F(X_{hi})-F(X_{lo}))^2} = \sqrt{\pm 1.5^2 \pm 2.4^2 \pm .7^2} = 5.8^\circ C$$

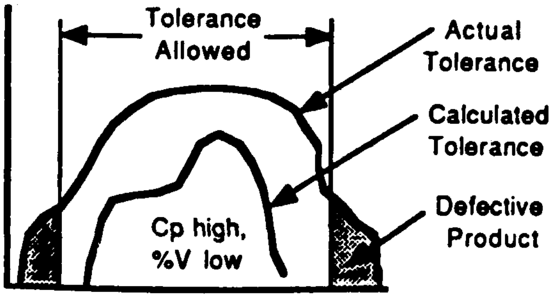
*Since X was known to be closer to the USL than the LSL only one calculation is shown.

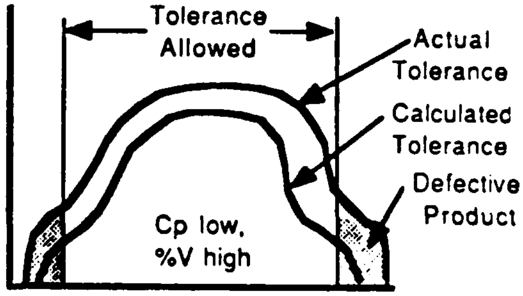
FIGURE A4

The Cp and Cpk calculated above represents only one of several Cps of the reflow process. Each critical response of the work cell has its own Cp and Cpk. The resulting workcell process capabilities index may be represented as the minimum Cpk of any of the workcell responses. Since the Cpk is a measure of observed "worst case" only and does not address the probability of occurrence of the "worst case", it does not directly quantify yields of less than 100 percent. This means that a process may have a Cpk of 0.5, and a yield of 99 percent. This situation would be caused by a collection of variables that are poorly controlled and have a wide range or large effect on the process, but also tend to be centrally distributed and rarely go to their extreme limits. In processes with a Cp of less than 1.00, each of the sub-variations caused by each variable can be given an estimated probability distribution that can be analyzed to generate process yield estimate. The relationship between the Cp and yield depends on the probability distribution estimate used for each variable. If the distributions are assumed to be normal, then the Cp would be worse than the yield by 20 or 40 percent, i.e., a process with a Cp of 0.6 could have a yield of 0.85 or 85 percent. If the distributions are more evenly distributed, then the Cp would tend to equal the yield, i.e., a process with a Cp of 0.85 could have a yield of 0.85 or 85 percent.

Various combinations of Cp, Cpk and %V values have different meanings. The desired situation is to have both a high Cp, Cpk and %V indicating that the process is robust and on target with a high degree of confidence. This means that there is a probability that an actual "safety margin" exists within the process (right). Other combinations of Cp and %V may exist, however. If the Cp and Cpk are high but the % of variability accounted for are low, then other unidentified variables or measurement errors are significantly affecting the process. The high %V indicates that additional activity should be planned to identify and quantify the unknown variable(s).







If the Cp and Cpk are low but the % of variability accounted for is high (above right), then the Cp and Cpk correctly indicates that the process is capable of producing defective products. This means that the process will simply need to be "fixed" to guarantee 100% yields. Since the %V indicates that the process is well-understood, the cause of the low yield probably lies within the identified variables and they need to be reinvestigated and alternate/additional means of process control explored. Alternate control may take the form of additional manual control charts, additional instrumentation, improvement in sensor or control technology, etc.

If the Cpk is less than the Cp, then the resulting distribution is not centered and the process has room for improvement even without changing the width of the process distribution.

Interoffice Correspondence
TRW Avionics & Surveillance Group

91.Q414.PCC.002

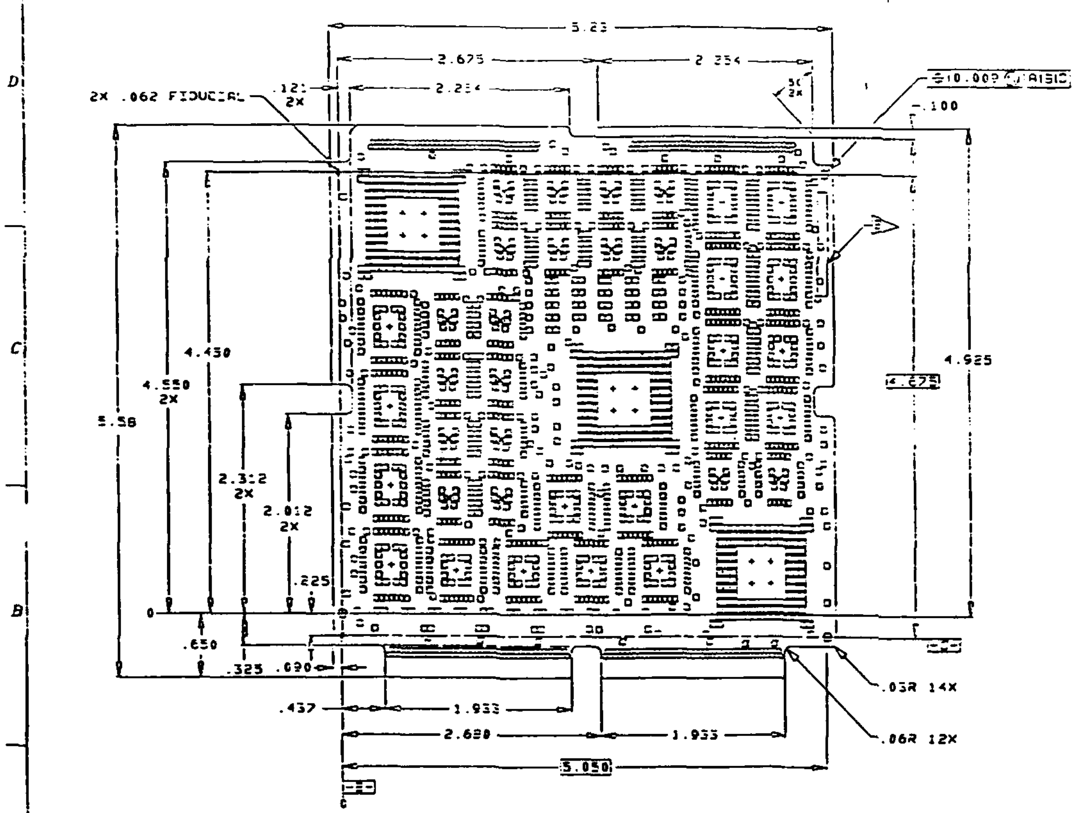
Subject	Date	From
EMPI PWB ARTWORK AND FABRICATION DRAWING	24 January 1991	P. CREPEAU

To	cc	Location/Phone
P. GLASER	D. CAVANAUGH J. MURRAY T. NEILLO G. SWIECH	RC4/1073/3182

Attached to this IOC is the artwork and the fabrication drawings for the test bed printed wiring board being used for the EMPI program.

TRW
EMPI
P4040 6 NOV 1990
BOARD AND STENCIL ARTWORK LIST

T786582-1/1	LAYER 1 - (COMPONENT SIDE)
T786582-1/2	LAYER 1 - (COMPONENT SIDE) STRETCHED .003"
T786582-2	LAYER 2 - (VCC)
T786582-3	LAYER 3 - (GND)
T786582-4	LAYER 4 - SOLDER SIDE
T786582-5/1	MASK - (.030 STANDOFF DOTS)
T786582-5/2	MASK - (.020 STANDOFF DOTS)
T786582-6/1	SOLDER PASTE (UPPER)
T786582-6/2	SOLDER PASTE (LOWER)
T786582-7	SILKSCREEN (REF DES)

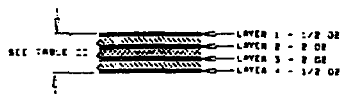


NOTES:

TABLE I

DRILL TABLE			
Symbol	Size	Plated	Qty
●	.010	P	290
□	.018	P	1904
x	.050	P	18
+	.070	P	30
⊖	.072±.001	U	3

TABLE II



LAYERING STACKUP
SCALE: NONE

NEXT ASSY | USED ON
APPLICATION

TRW

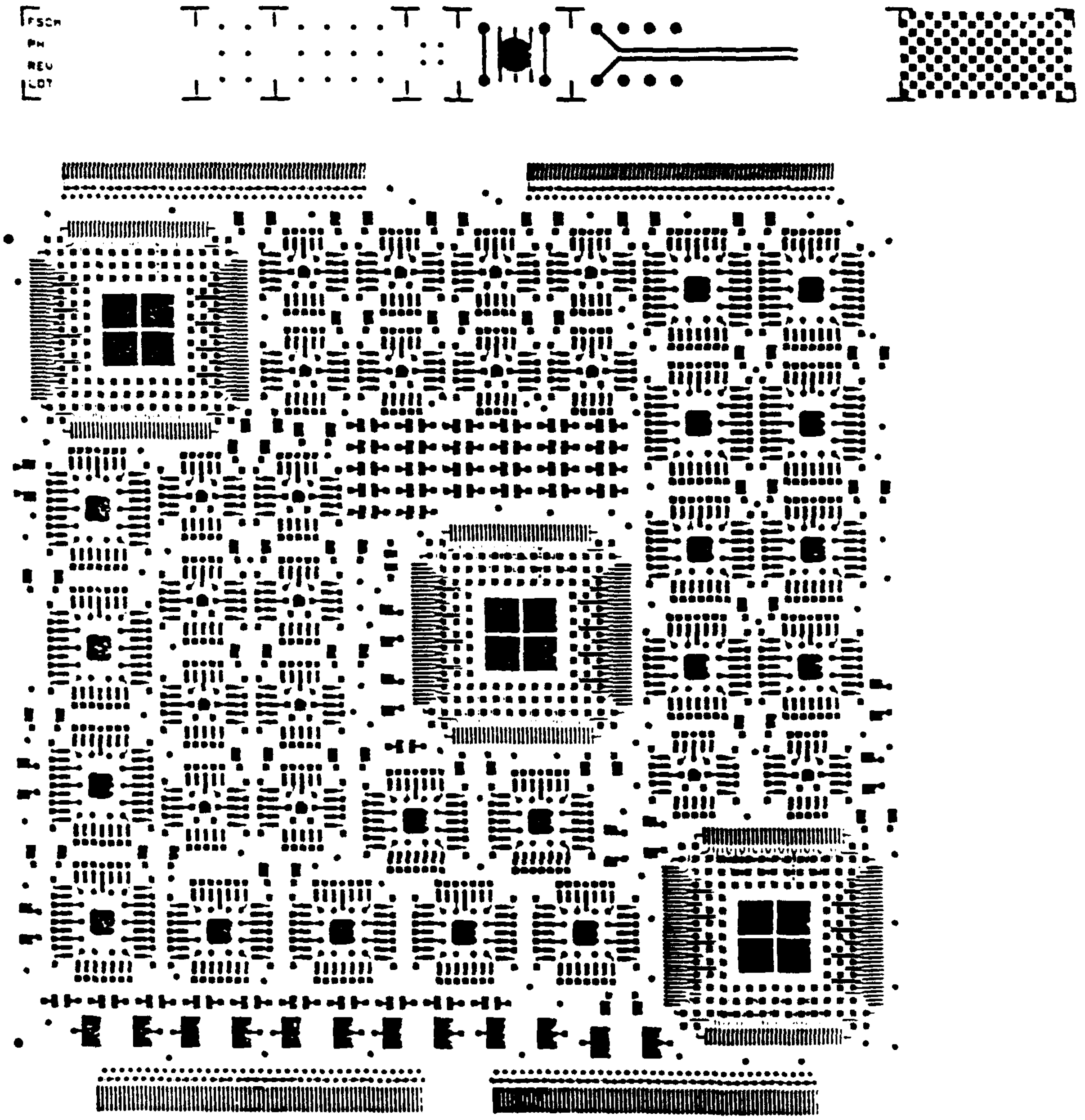
FABRICATION DRAWING
EMPI

D 786582

SCALE 2/1

T736532-1/1

TRW
EMPI
P.4040 6 NOV 1990
LAYER 1 - (COMPONENT SIDE)
DESIGNED BY QC DESIGN



T736532 - 1/2

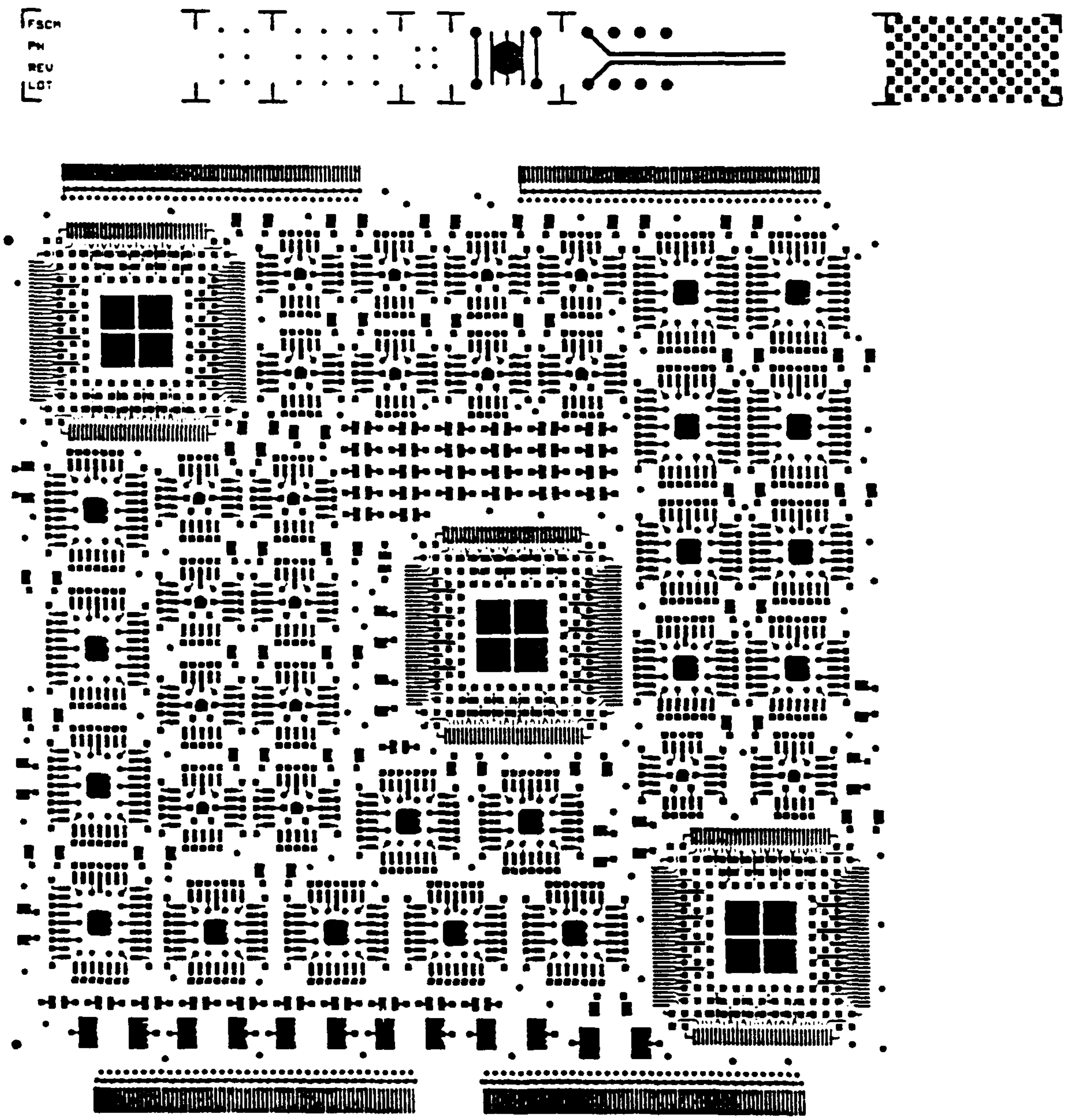
TRW

EMPI

P.4040 6 NOV 1990

LAYER 1 - (COMPONENT SIDE)

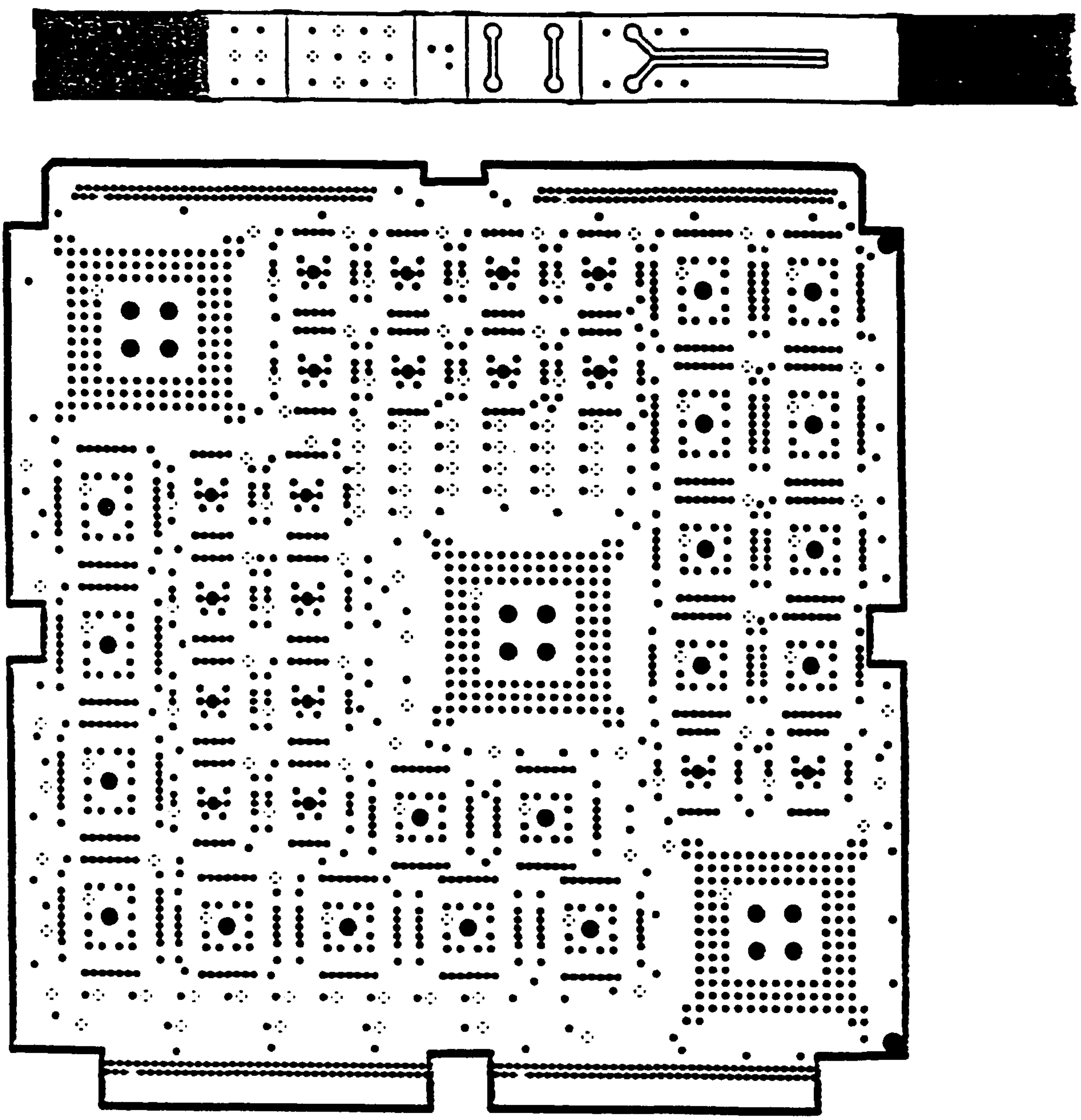
DESIGNED BY QC DESIGN



"STRETCHED .003 OVERALL"

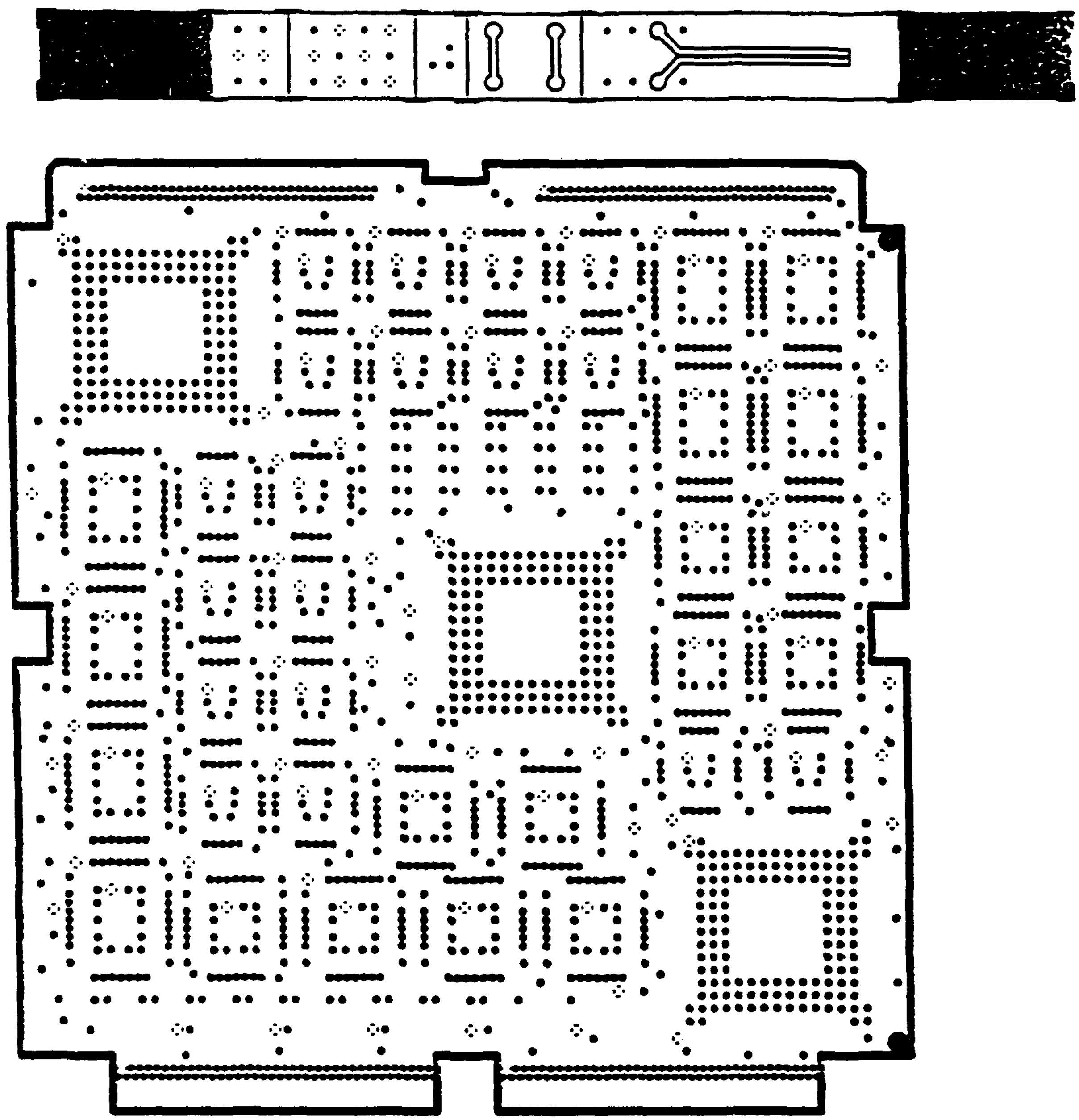
T736532-2

TRW
EMPI
P.4040 6 NOV 1990
LAYER 2 - (VCC)
DESIGNED BY QC DESIGN



T736332-3

TRW
EMPI
P.4040 6 NOV 1990
LAYER 3 - (GND)
DESIGNED BY QC DESIGN



T736352-4

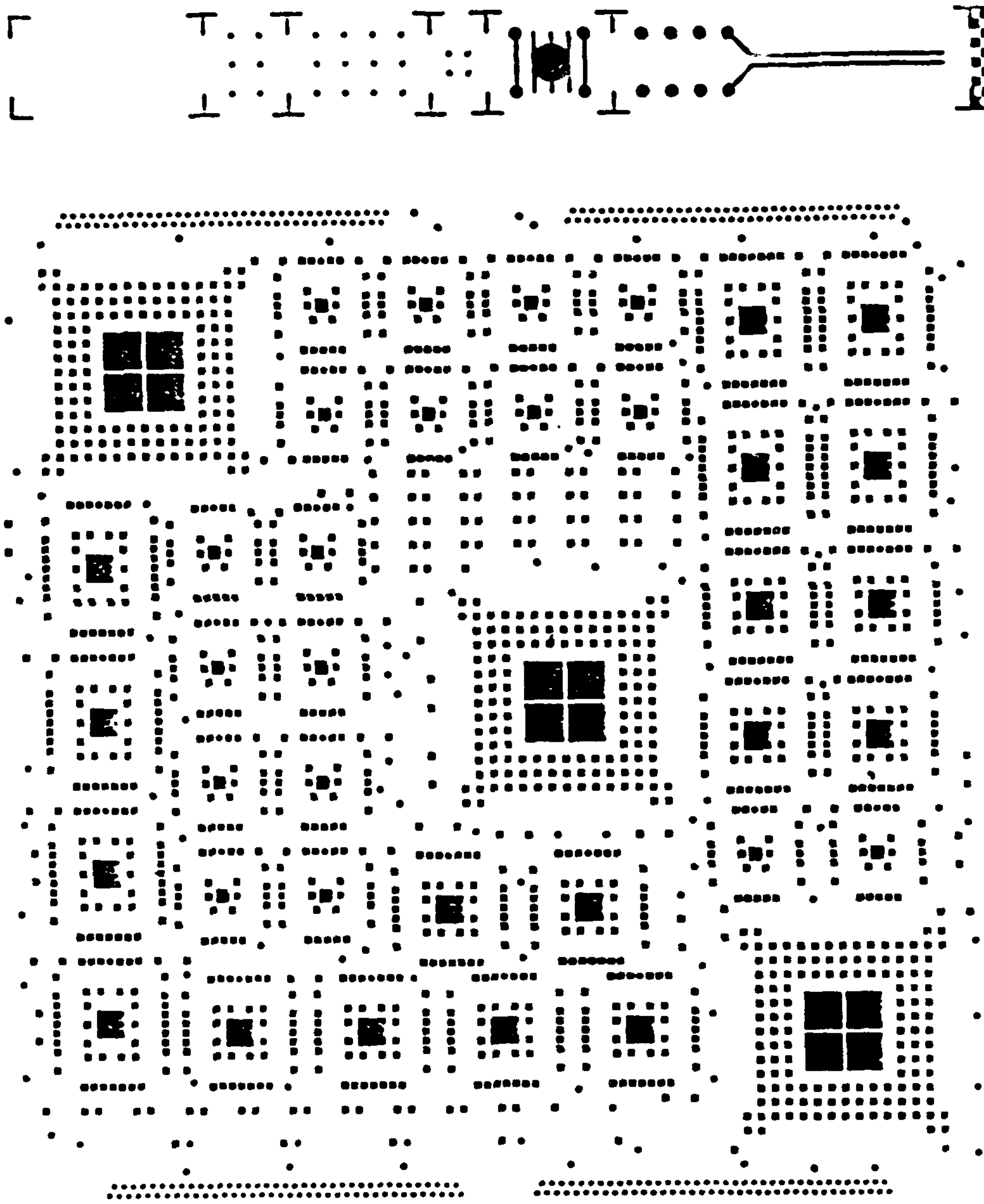
TRW

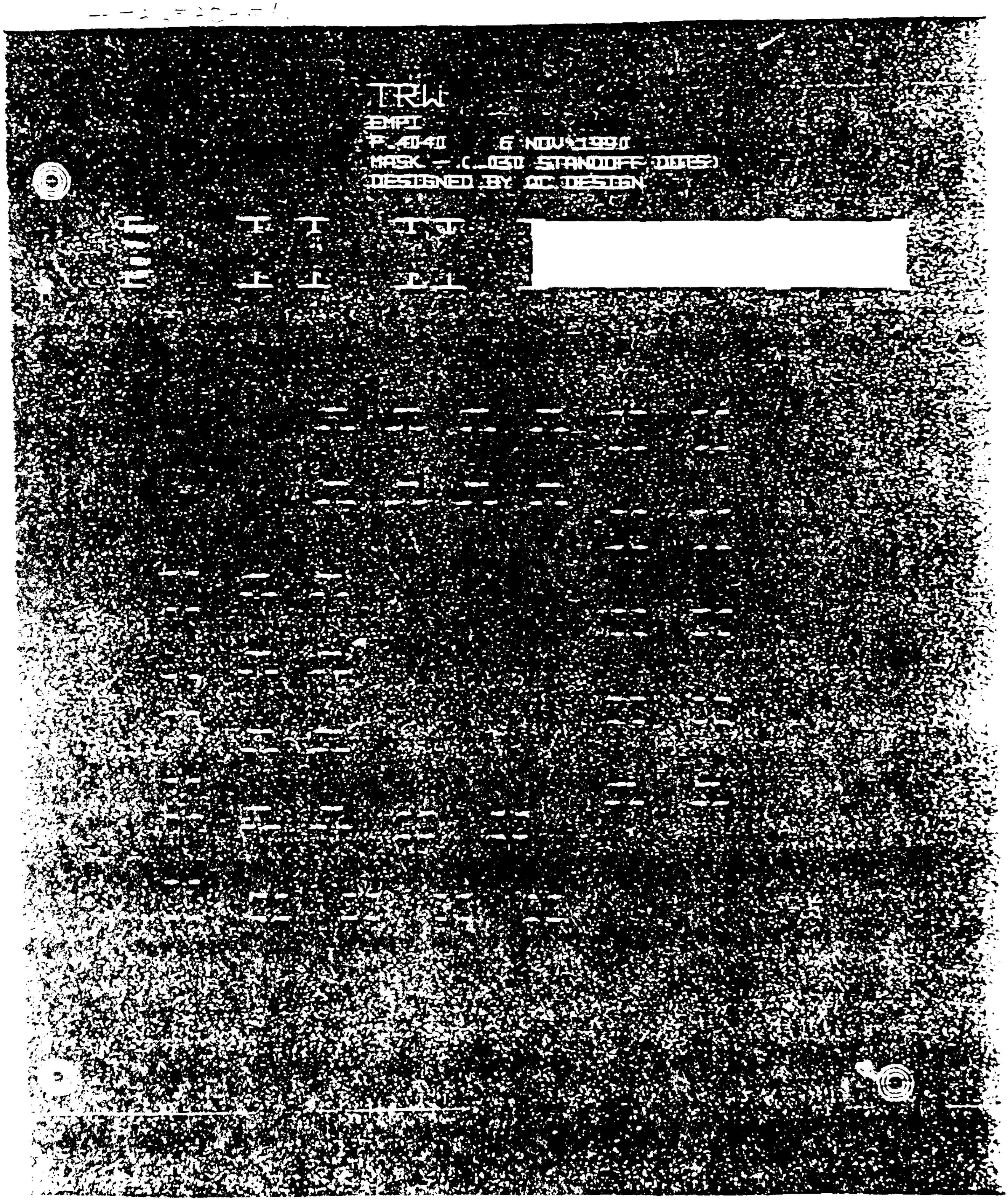
EMPI

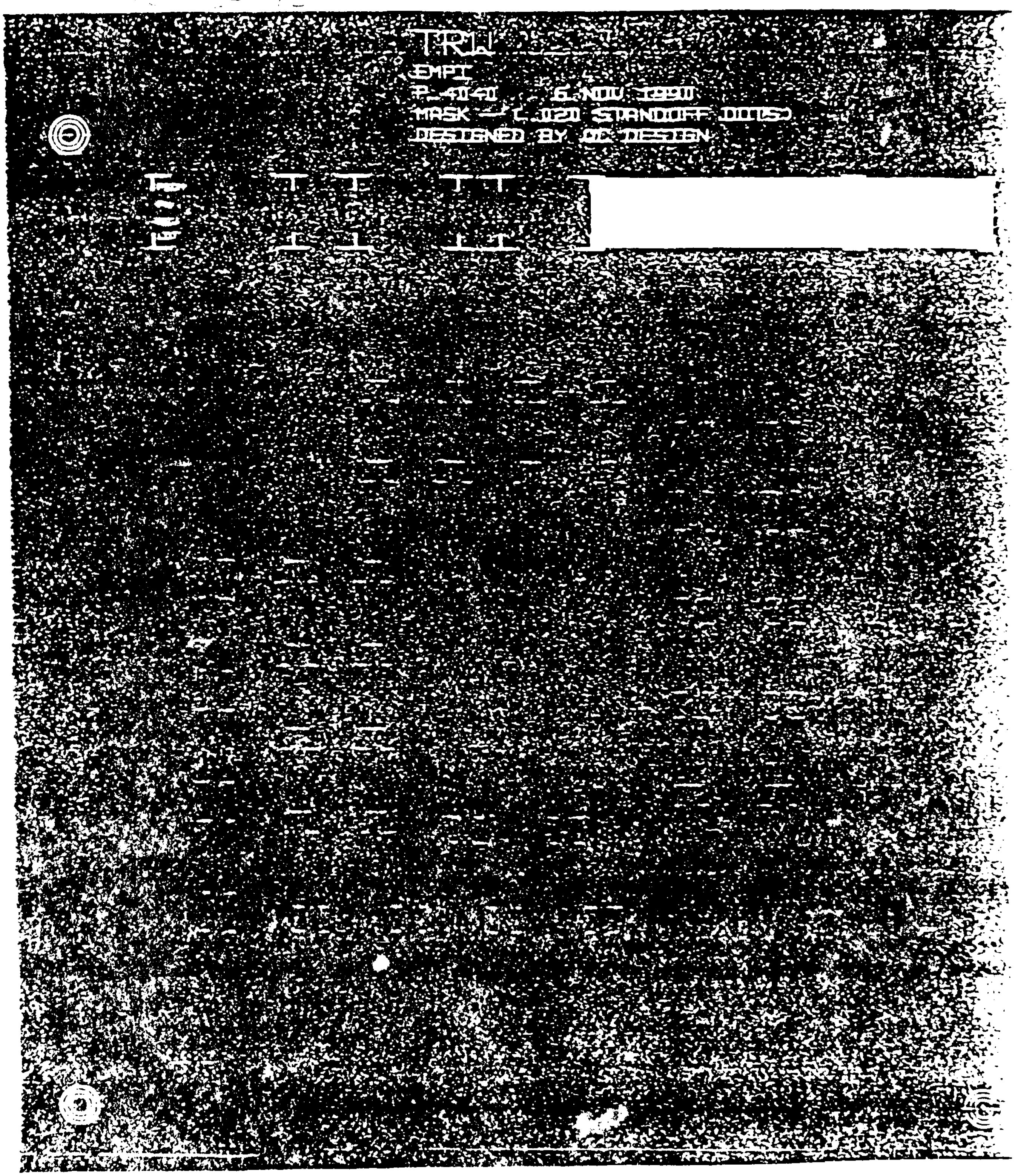
P.4040   6 NOV 1990

LAYER 4 - SOLDER SIDE

DESIGNED BY QC DESIGN

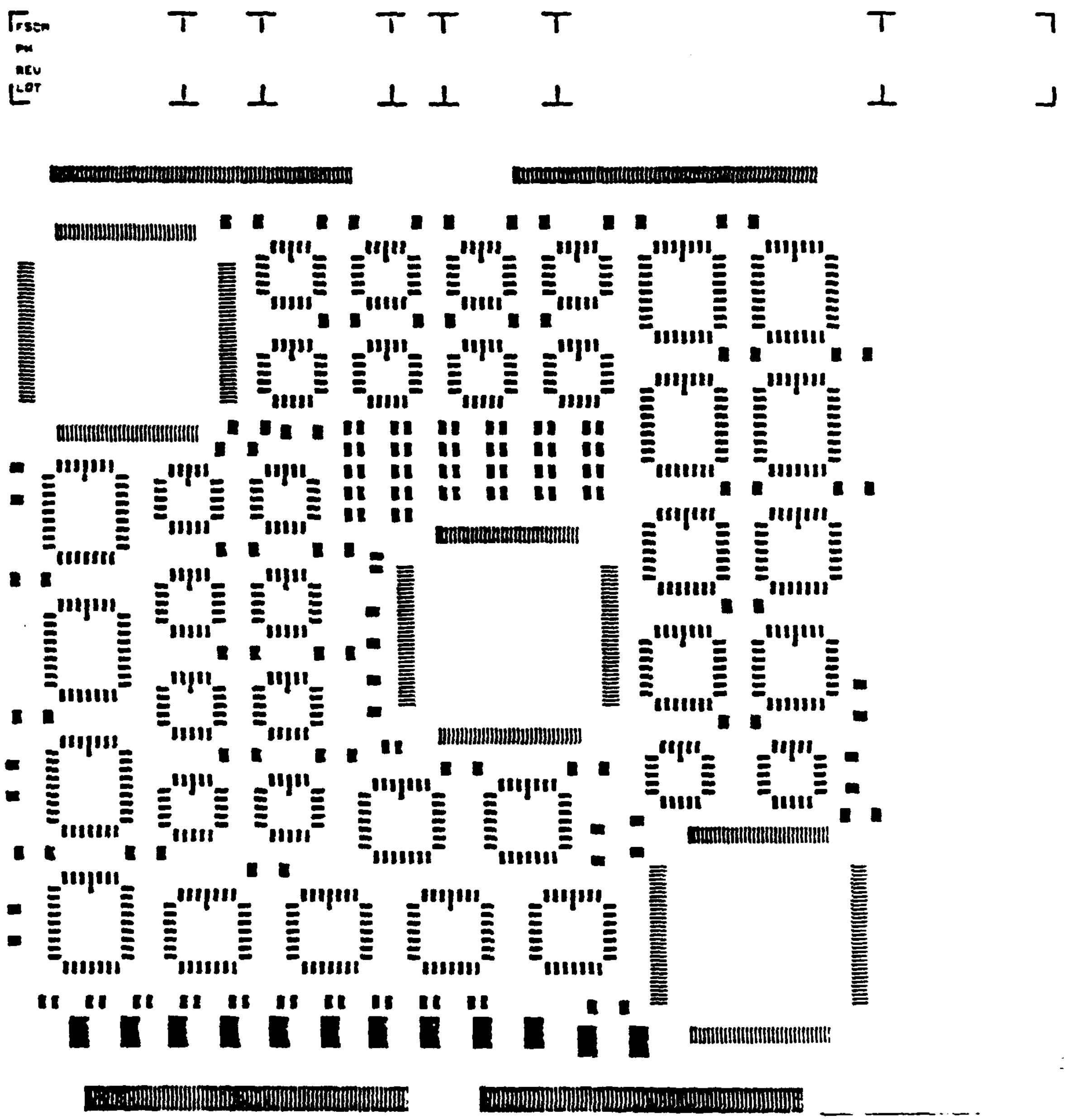



TRW
EMPI
6 NOV 1990
MASK - (.030 STANDOFF DOTS)
DESIGNED BY


TRW
EMPI
P-4040
6 NOV 1990
MASK
STANDOFF
DESIGNED BY
DESIGN

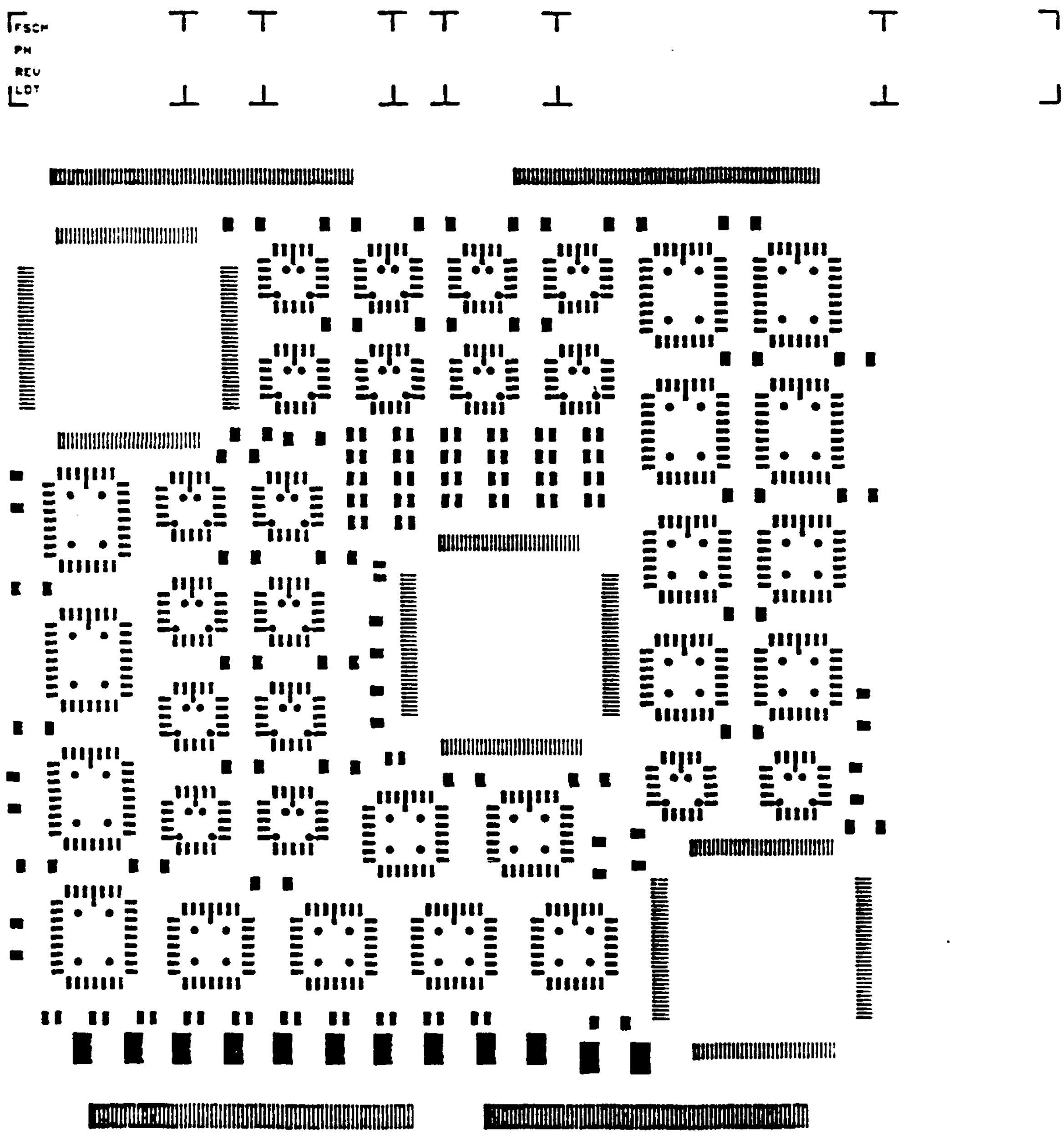
T736532-6/1

TRW
EMPI
P.4040 6 NOV 1990
SOLDER PASTE (UPPER)
DESIGNED BY QC DESIGN



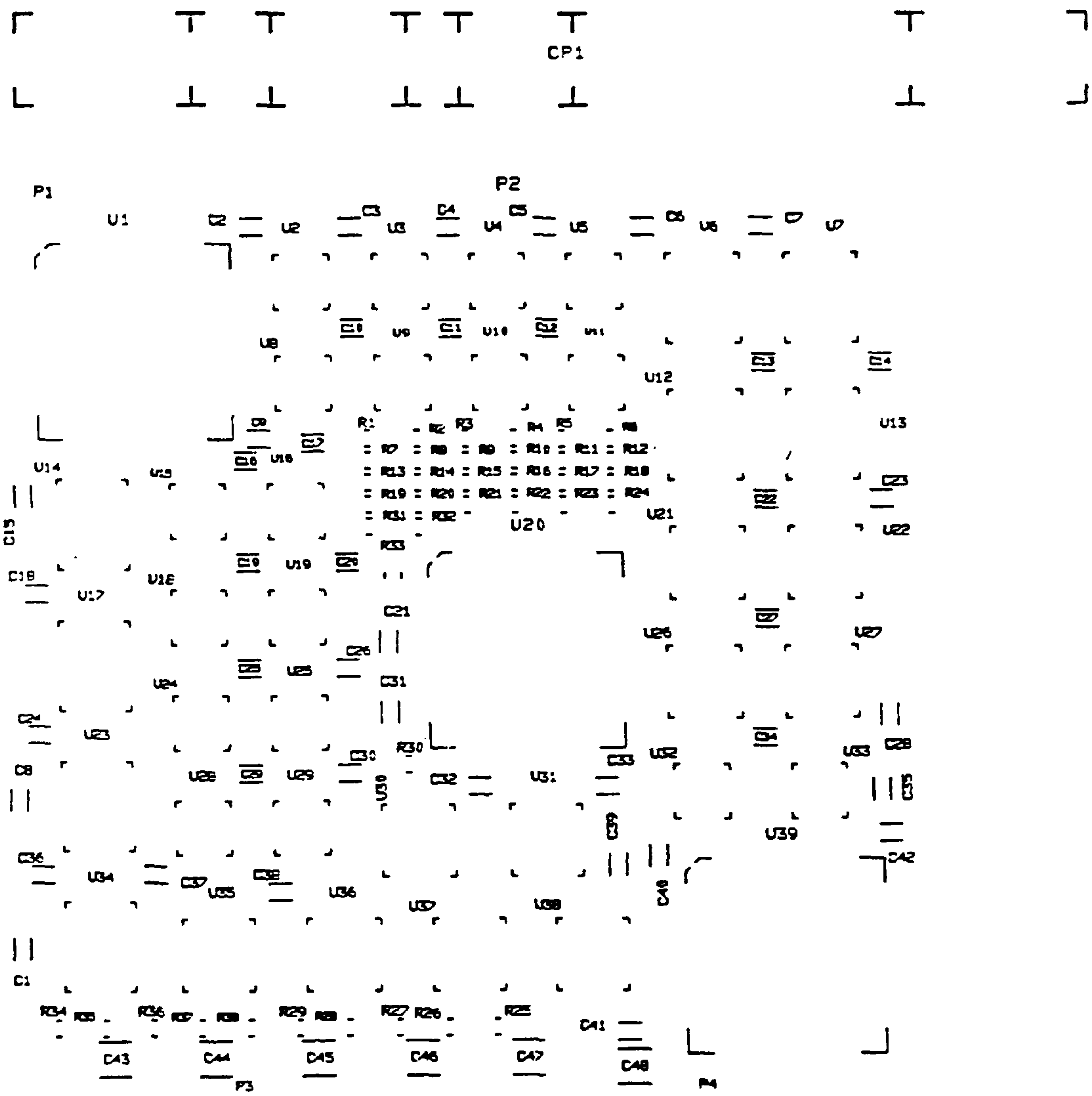
T736582-6/2

TRW
EMPI
P.4040 6 NOV 1990
SOLDER PASTE (LOWER)
DESIGNED BY QC DESIGN



T736582-7

SILKSCREEN



EMPI Project PWB Bill of Material

Description	Qty/unit	Units	Total w/ 5% attrn	Notes	Potential Vendor	Lead Finish	Shipping Package
132 lead FPD case with cover	3	132	576*	Obtain from 4 vendors (143 parts per vendor)	Kyocera, NTK, Bourns	Gold on Nickel	tray
20 pin LCC case with cover	18	132	2495	From same vendor	TI	Solder Dip	tube
28 pin LCC case with cover	10	132	1386	From same vendor	TI	Solder Dip	tube
32 pin LCC case with cover	8	132	1109	From same vendor	TI	Solder Dip	tube
Chip resistor .075L x .050W x .040H	38	132	5267	From same vendor	-	Solder on Nickel	tape
Ceramic multilayer chip capacitor .180L x .050W x .035H	42	132	5821	From same vendor	-	Solder on Nickel	tape
Tantalum chip capacitor .285L x .150W x .110H	6	132	832	From same vendor	Mepco/Electra	Solder on]Nickel	tape
PWB	1	142	150*	32 PWB's of 4 types, 7 PWB of 2 types See PWB SOW's.	Quick Circuits	See Dwg.	N/A

* Quantities for these parts reflect additional requirements beyond the 132 sets of parts.

TRW ELECTRONIC PRODUCTS INC
COLORADO SPRINGS, COLORADO
CODE IDENT 07367

TITLE

ELECTRONIC MANUFACTURING PROCESS IMPROVEMENT (EMPI) FOR PRINTED WIRING ASSEMBLIES/BOARDS

PRODUCT ASSURANCE PLAN

DATE: February 12, 1991 **NO:** EMPI-001

REVISIONS: See revision record

PREPARED BY: Norman N. Hahn
Product Assurance

APPROVAL SIGNATURES:

FOR John Lane
TRW/EPI Product Assurance Manager

Peter Glaser
EMPI Program Manager

TRW FORM 83-024

TRW

Electronic Products Inc.

REVISION RECORD

NO. EMPI-001

REV.	DATE	AUTHORIZATION	CHANGE	PAGES AFFECTED
---		New Release		

TRW EP 70-032 (FILE DIRECTLY AFTER COVER SHEET)

TABLE OF CONTENTS

1.0 PURPOSE

This plan describes the methods necessary to measure the experiment results from the Electronic Manufacturing Process Improvement (EMPI) program.

2.0 SCOPE

This plan will define the equipment and measurements to be made to evaluate the results of the five experiments in the EMPI program. These experiments are titled and numbered: T1/PC, reflow; T2/TM, tinning; T3/JM, cleaning; T4/TM forming, and T5/JM and TN, paste and placement.

3.0 MEASUREMENT EQUIPMENT

The following equipment will be used to measure the results of these experiments.

EQUIPMENT	ACCURACY REQUIRED
Coordinatograph - Cordax RM 30	0.1 mil
Optical comparator - Deltronic MPC-1	0.1 mil
Microscan model 150	0.15 mil
Microscope - stereo zoom with Unitron WFH10XR reticle eyepiece	0.2 mil
Zeiss universal microscope with Unitron filar eyepiece	0.1 mil
Zeiss universal microscope with Nomarski difference interference contrast and Epiplan 4.0 or 8.0 objective with polarizer	0.1 mil
Dial micrometer	0.1 mil

EQUIPMENT	ACCURACY REQUIRED
Surface gauge	0.1 mil
Thermocouple	1.0°C
Wester Ionograph model ICOM 4000	1 μgm NaCl/sq-in.
Oven	2.0°C
Faxitron x-ray with Kodak M film or equivalent	1.0 mil

4.0 PROCEDURE

The measurements taken and recorded to evaluate each experiment will follow the detailed experiment plan. The measurements for each experiment are identified as process and response measurements. Each experiment is addressed separately in the following paragraphs.

4.1 IR REFLOW EXPERIMENT, TI/PC

The following measurements are planned.

4.1.1 Process Measurements

VARIABLE	EQUIPMENT	RESOLUTION
■ PWB thickness	Dial micrometer	0.1 mil
■ PWB plating	By visual inspection	
■ PWB plating aging	Steam ager	1.0 minute
■ Tinned lead aging	Steam ager	1.0 minute
■ Solder paste stencil thickness	Dial micrometer	0.1 mil

VARIABLE	EQUIPMENT	RESOLUTION
■ Solder paste aging	Oven at 95°C	2°C 15 minute
■ Solder paste placement	Zeiss universal microscope with Nomarski difference interference contrast and Epiplan 4.0 and 8.0 objective with polarizer	0.1 mil
■ Component placement	Same as above	

4.1.2 Response Measurements

VARIABLE	EQUIPMENT	RESOLUTION
■ Solder joint reflectance	Visual comparison	Flat (1) to specular (5)
■ Solder joint finish	Visual comparison	Smooth (1) to rough (5)
■ Lead pad alignment	Zeiss universal microscope with Nomarski difference interference contrast and Epiplan 4.0 or 8.0 objective with polarizer	0.1 mil
■ Solder heel fillet height	Microscope - stereo zoom (locked at 3X) with Unitron WFH10XR reticle eyepiece	0.2 mil
■ FPD soldered lead de-wetting	Zeiss universal microscope with particle-counting grid on video monitor	
■ FPD soldered lead solder volume	Visual comparison	Standard to be established

VARIABLE	EQUIPMENT	RESOLUTION
■ Solder balls	Faxitron x-ray with Kodak M film or equivalent film	1.0 mil
	Zeiss universal microscope with Nomarski difference interference contrast and Epiplan 4.0 or 8.0 objective with polarizer	0.1 mil
■ Solder joint temperature	Mole with thermocouple	1°C

4.2 FINE PITCHED DEVICE TINNING, T2/TM

The following measurements are planned.

4.2.1 Process Measurements

VARIABLE	EQUIPMENT	RESOLUTION
■ Lead aging	Steam aging cabinet	0 to 6 months
■ Lead cleanliness	10% solvent of oil	Clean to contaminated
■ Belly-to-toe dimension	Microscan model 150 (with PRS 150 laser sensor)	0.15 mil

4.2.2 Response Measurements

VARIABLE	EQUIPMENT	RESOLUTION
■ Solder coverage at calf	Microscope - stereo zoom (locked at 3X) with Unitron WFH10XR reticle eyepiece	0.2 mil

VARIABLE	EQUIPMENT	RESOLUTION
■ Solder thickness at calf	Metallurgical microsection - Zeiss universal microscope with Unitron filar eyepiece	0.1 mil
■ Non-wet solder surface	Zeiss universal microscope with particle-counting grid on video monitor	Visual evaluation
■ De-wet solder surface	Zeiss universal microscope with particle-counting grid on video monitor	Visual evaluation
■ Icicles	Microscope - stereo zoom (locked at 3X) with Unitron WFH10XR reticle eyepiece	0.2 mil
■ Lead-to-lead gap reduction	Zeiss universal microscope with Nomarski difference interference contrast and Epiplan 4.0 or 8.0 objective with polarizer	0.1 mil

4.3 PWA CLEANING T3/JM

The following measurements are planned.

4.3.1 Process Measurements

VARIABLE	EQUIPMENT	RESOLUTION
■ Time since reflow	Timer	1 minute
■ Reflow temperature	Thermocouple	1°C
■ Nitrogen environment	Oxygen analyzer	2%
■ Component standoff height	Surface gauge	0.1 mil

VARIABLE	EQUIPMENT	RESOLUTION
■ Solder paste vendor	Vendor designation	N/A

4.3.2 Response Measurements

VARIABLE	EQUIPMENT	RESOLUTION
■ Visual cleanliness	Comparison to visual standards	1 to 5 units
■ Ionic cleanliness	Wester Ionograph model ICOM 4000	1 μgm NaCl/sq-in

4.4 FINE PITCHED DEVICE LEAD FORMING, T4/TM

The following measurements are planned.

4.4.1 Process Measurements

VARIABLE	EQUIPMENT	RESOLUTION
■ Lead colinearity, skew	Coordinatograph-Cordax RM 30	0.1 mil
■ Lead thickness	Optical comparator-Deltronic MPC-1	0.1 mil
■ Lead package egress	Microscan model 150 (with PRS 150 laser sensor)	0.15 mil

4.4.2 Response Measurements

VARIABLE	EQUIPMENT	RESOLUTION
■ Skew	Coordinatograph - Cordax RM 30	0.1 mil
■ Coplanarity	Microscan model 150 (with PRS 150 laser sensor)	0.15 mil
■ Belly-to-toe dimension	Microscan model 150 (with PRS 150 laser sensor)	0.15 mil

VARIABLE	EQUIPMENT	RESOLUTION
■ Toe-to-toe dimension	Coordinatograph - Cordax RM 30	0.1 mil
■ Toe angle dimension	Microscan model 150 (with PRS 150 laser sensor)	0.15 mil
■ Toe burrs	Microscope - stereo zoom (locked at 3X) with Unitron WFH10XR reticle eyepiece	0.2 mil

4.5 PASTE REGISTRATION, T5/JM PART 1

The following measurements are planned.

4.5.1 Process Measurements

VARIABLE	EQUIPMENT	RESOLUTION
■ Fudical pad stretch	Coordinatograph cordax rm 30	0.1 mil
■ PWB plating	By visual inspection	N/A
■ Solder paste vendor	By vendor designation	N/A

4.5.2 Response Measurements

VARIABLE	EQUIPMENT	RESOLUTION
■ Registration	Zeiss universal microscope with Nomarski difference interference contrast and Epiplan 4.0 or 8.0 objective with polarizer	0.1 mil
■ Smear	Same as above	0.1 mil

VARIABLE	EQUIPMENT	RESOLUTION
■ Slumping	Same as above	0.1 mil
■ Thickness	Microscan model 150 (with PRS 150 laser sensor)	0.15 mil
■ Spikes	Microscope - stereo zoom Microscan model 150 (with PRS 150 laser sensor)	0.15 mil

4.6 COMPONENT PLACEMENT, T5/TN PART 2

The following measurements are planned.

4.6.1 Process Measurements

VARIABLE	EQUIPMENT	RESOLUTION
■ Solder paste open time	Timer	1 minute
■ PWB plating	By inspection	N/A
■ PWB thickness	Dial micrometer	0.1 mil
■ Tinned lead aging	Steam ager	1 minute
■ Fudicial pad stretch	Coordinatograph-Cordax RM 30	0.1 mil

4.6.2 Response Measurements

VARIABLE	EQUIPMENT	RESOLUTION
■ Lead/pad alignment	Zeiss universal micrcoscope with Nomarski difference interference contrast and	0.1 mil

VARIABLE	EQUIPMENT	RESOLUTION
	Epiplan 4.0 or 8.0 objective with polarizer	
■ Lead and toe overhang	Same as above	0.1 mil
■ Chip components overhang	Same as above	0.1 mil
■ Heel clearance	Microscope - stereo zoom (locked at 3X) with Unitron WFH10XR reticle eyepiece	0.2 mil
■ Leadless chip carriers overhang	Stereo zoom as above	0.2 mil
■ Lead penetration into solder paste	Microscan model 150 (with PRS 150 laser sensor)	0.15 mil

Cost of Quality Worksheet

Dept/Area ______________ Burden Rate = $______

A. Prevention Costs

1. *Training (New Hire, Internal/Gvt. Std. In-Service)*

# of New Hires	______	
x Hours Training/Person	______	
x Burden Rate =		$______
+ (For Internal Certification)		
# of In-Service Personnel	______	
x Hours Training/Person	______	
x Burden Rate =		$______
+ (Government Standard Certification)		
# of In-Service Personnel	______	
x Hours Training/Person	______	
x Burden Rate =		$______

2. *Documentation*

Time spent preparing and using documentation and Forms for new methods and machinery (hours)	______	
x Burden Rate =		$______

3. *Maintenance and Calibration*

# of Downtime Hours	______	
x Cost of Downtime/Hour =		$______
Cost of External Maintenance/ Calibration Service		$______
# of Internal Personnel Involved	______	
x # of Hours	______	
x Burden Rate =		$______

4. *SPC Implementation*

# of Hours Spent Preparing/ Interpreting Charts/Person	______	
x # of Personnel	______	
x Burden Rate =		$______
# of Hours Training in SPC	______	
x # of People in Training Program	______	
x Burden Rate =		$______

A. Prevention Costs (continued)

5. DOE

# of Hours Running Experimentation	______	
x # of People	______	
x Burden Rate =		$ ______
# of Hours Spent Preparing/ Interpreting Data/Person	______	
x # of Personnel	______	
x Burden Rate =		$ ______
# of Hours Training in DOE	______	
x # of People in Training Program	______	
x Burden Rate =		$ ______

6. Cost of Hardware and Software Needed for Quality Monitoring $ ______

7. Receiving Inspection

# of Hours Spent Inspecting Received Goods	______	
x # of Personnel Involved in Inspection	______	
x Burden Rate =		$ ______

8. Vendor Quality Program

# of Hours at Vender Site	______	
# of Personnel	______	
x Burden Rate		$ ______
Travel and Living Expenses		$ ______
# Hours Review Vendor	______	
SPC/Process Reports	______	
# of Personnel	______	
x Burden Rate		$ ______
# Hours Spent On Vendor Qual/Cert	______	
# of People	______	
x Burden Rate		$ ______

Total Cost of Prevention (Lines 1 - 7) $ ______

B. Appraisal Costs

1. ***Inspection***
   - \# of Personnel ______
   - x # of Hours Spent Inspecting (1st pass only) ______
   - x Burden Rate = $ ______

2. ***Checking Labor***
   - \# of Operators Self-Inspecting ______
   - x Hours Spent/Person ______
   - x Burden Rate = $ ______

3. ***Set-up and Maintenance for Equipment***
   - \# of Hours Setting Up Equipment ______
   - x # of Personnel ______
   - x Burden Rate = $ ______

4. ***Q.A. Review***
   - \# of Personnel ______
   - x # of Hours ______
   - x Burden Rate = $ ______

5. ***Engineering Review of Designs***
   - \# of Personnel ______
   - x # of Hours ______
   - x Burden Rate = $ ______

6. ***Cost of Materials and Inspection Equipment*** $ ______

7. ***Cost of External Maintenance and Calibration of Inspection Equipment*** $ ______

Total Cost of Appraisal $ ______

C. Internal Failures

1. Scrap Costs

# of Scrapped Items	______	
x Material Costs/Item =		$ ________
# of Scrapped Items	______	
x Labor Hours Invested in Each Scrapped Item	______	
x Burden Rate =		$ ________

2. MRB Costs

# of MRB Personnel	______	
x Hours of MRB Meeting	______	
x Burden Rate =		$ ________

3. Rework

# of Internal Labor Hours to Bring Product Back to Same Inspection Step (including re-inspection and retesting)	______	
x # of Rework Items	______	
x Burden Rate =		$ ________
# of Rework Items	______	
x External Parts and Labor Costs to Bring Product Back to This Stage =		$ ________
# of Rework Items	______	
x Time to Report/Reorder (Hours)	______	
x Burden Rate =		$ ________

4. Penalties for Failure to Meet Schedule =	$ ________
5. Cost of Specification Waivers =	$ ________

6. Additional Production Cost

# of Personnel	______	
x Hours of Activity	______	
x Burden Rate =		$ ________

Total Internal Cost Failures $ ________

D. External Failures

1. ***Processing Returns***
   - # of Returns ______
   - x # Hours Processing Each Return ______
   - x Burden Rate = $ ______

2. ***Cost of Field Activity***
   - # of Hours Spent In Field Due To Customer Complaints ______
   - x Burden Rate = $ ______
   - Traveling and Living Expenses $ ______

3. ***Cost Of Business Lost Due To Customer Dissatisfaction (Estimate)*** $ ______

4. ***MRB Costs***
   - # of MRB Personnel ______
   - x Hours of MRB Meeting ______
   - x Burden Rate = $ ______

5. ***Rework***
   - # of Internal Labor Hours to Bring Product Back to Same Inspection Step (including re-inspection and retesting) ______
   - x # of Rework Items ______
   - x Burden Rate = $ ______
   - # of Rework Items ______
   - x External Parts and Labor Costs to Bring Product Back to This Stage = $ ______
   - # of Rework Items ______
   - x Time to Report/Reorder (Hours) ______
   - x Burden Rate = $ ______

Total External Cost Failures $ ______

Total Cost Of Quality (Prevention, Appraisal, Internal and External Failures) $ ______

Total Failure Costs (Internal + External) $ ______

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